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Corps of Engineers

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Washington District

SECURITY INFORMATION

SPECIAL STUDY S-53-2

DRAU (DRAVA) RIVER

ARTIFICIAL FLOODING POTENTIALITIES

PREPARED BY
MILITARY HYDROLOGY R&D BRANCH
ENGINEERING DIVISION
WASHINGTON DISTRICT, CORPS OF ENGINEERS
WASHINGTON, D. C.
MAY 1953

SECURITY INFORMATION

SPECIAL STUDY S-53-2

DRAU (DRAVA) RIVER
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TABLE OF CONTENTS

SPECIAL STUDY S-53-2
DRAU (DRAVA) RIVER*
ARTIFICIAL FLOODING POTENTIALITIES

SECTION I
INTRODUCTION

1-01 ASSIGNMENT.

This special study was assigned to the Military Hydrology R&D Branch, Engineering Division, Washington District by letter from Office, Chief of Engineers, ENGWE, to the Division Engineer, North Atlantic Division; subject "Military Hydrology R&D Project No. 8-72-12-001; Special Assignment" dated 9 January 1953.

1-02 PURPOSE AND SCOPE.

a. This report presents information regarding the hydraulic nature of artificial flooding potentialities in the DRAU (DRAVA)* River Basin. It covers the main stems of the DRAU and MUR (MURA)* Rivers.

b. The report consists largely of a compilation and consolidation of information presented in various intelligence documents and technical publications, with certain supplementary analyses and discussions. The material forming the basis of this report was limited to that available in the Washington, D. C. area, or obtainable from other sources within the time allotted for the study. Detailed analyses were confined to those elements deemed capable of the greatest military effect. Generalized qualitative evaluation was made of less critical elements to determine their relative potentialities. Considerable additional engineering data would be required to permit a comprehensive investigation of the complete area. Such investigation probably would produce quantitative results affording a more complete and detailed picture of the artificial flooding potentialities of the DRAU River Basin.

c. The report is designed to furnish basic data and results of analyses needed to answer questions concerning:

(1) Normal and extreme discharges, stages, and velocities at key stations on the DRAU and MUR Rivers.

(2) Stream characteristics including gradients, depths, and widths of channel and flood-plain on those streams.

(3) Data concerning locations and zero elevations of gaging stations.

*German and Austrian name (Slavic name)

(4) Data concerning locations and dimensions of dams, bridges, and hydroelectric projects.

(5) The extent of flooding possible by erection of temporary dams on the DRAU and MUR Rivers.

(6) The magnitude and duration of flood waves and flow variations created by breaching or regulated discharge from major dams and reservoirs, and their effect on military bridging and crossing operations on the DRAU and MUR Rivers.

1-03 ARRANGEMENT.

This report is sub-divided as follows:

Section I	Introduction
Section II	Drainage Basin Characteristics and Developments
Section III	Hydrologic Characteristics
Section IV	Artificial Flood Potentialities
Section V	Effect on Military Operations
Bibliography	
Tables	
Plates	
Exhibit A	Abstracts of Technical Literature on the DRAU (DRAVA) River
Exhibit B	Abstracts of Technical Literature on the MUR (MURA) River

1-04 DEFINITIONS AND REFERENCE DATUM.

a. Equivalent English-Metric Terms. Most values used in this report are in the Metric System. Conversion factors for the English and Metric systems are presented for convenient reference in Table 1.

b. Abbreviations. The following abbreviations are used in this report:

cm	centimeters
HP	Horsepower (metric)
hr	hours
km	kilometers
km^2	square kilometers
KW	kilowatts
KWH	kilowatt hours
m	meters
mm	millimeters
m/sec	meters per second
m^3	cubic meters
m^3/sec	cubic meters per second
rpm	revolutions per minute

1-04

c. Hydrologic Terms. Special hydrologic abbreviations, in conformance with standard German and Austrian hydrologic practice, are defined in Table 2.

d. Elevation Datum. Elevations are in meters above the Adriatic Sea, "meters ueber Adria" (m.u.A.), the standard Austrian altitude datum.

e. River Distances. In this report, distances are expressed in kilometers measured as follows:

(1) DRAU River: Kilometers from the old 1912 Austrian-Hungarian border (262 km above the mouth), positive values increasing upstream and negative values downstream. This conforms to the system used in the available official pre-World War II Austrian hydrologic publications. On the DRAU River profiles, a secondary scale is also shown, expressed as kilometers upstream from the confluence of the DRAU and DANUBE Rivers. This conforms to the official Yugoslavian kilometrage system for the 148 km long reach upstream to the head of navigation at BARCS. River distances as used in this report for the reach between BARCS and the old Austrian-Hungarian border were scaled from maps and adjusted to conform with available official hydrologic kilometrage. Starting points and listed kilometrage of various established river measurement systems in this area vary considerably, changing with political and territorial revisions and with shifts in the river course. Current Austrian hydrologic practice bases the zero kilometer at the present Austrian-Yugoslav border, 403 km above the DRAU-DANUBE confluence.

(2) MUR River: Kilometers upstream from the confluence of the MUR and DRAU Rivers. This conforms to the system currently used in the official Austrian Water Power Registers (Wasserkraft-Kataster). Some other Austrian publications start their river measurements at the Austrian border, 74 km above the mouth of the MUR River.

(3) Other Rivers: Kilometers upstream from their mouths, corresponding to Austrian hydrologic practice.

f. Grid System. Grid references cited in this report are to the "Universal Transverse Mercator" (U.T.M.) Grid system unless otherwise designated.

g. Maps. The area of the DRAU River basin is covered by the following available standard American-British military maps:

1-04

Scale	Map Series AMS	Map Series GSGS	Sheet Numbers
1:250,000	M591	4230	6, 7, 7B
	M506	4413	Y2-Y6, Y16
	M508	4346	N48-048
1:100,000	M691	4164	4B-F, 13, 14, 14A, 14B
	M607	4396	2-7, 13-17, 31-35
	M641	4416	Y9-10, Z8-10
1:50,000	M791	4229	4B-F/I-IV, 13/I, 14-14B/I&IV
	M702	4737	4-7/II&III, 14-15/I&IV, 16/III, 31/I, 32/III; 33/I
	M771	4529	Z6/8, Z7/5-8, Z8/5-8, Z9/3-8, Z10/1&5, 4/I&IV, 5/I&IV
	M773	4728	5458W, 5558E, 5659E, 5660W, 5660E, 5661W
	CAPTURED MAPS		
1:25,000	AMS CALL NO.: 17-M 3-30.5 49005-25		5250-5251/1-4, 5350/1-4, 5351/1-3, 5352/1, 3&4, 5353/2-4, 5341/1-4, 5455/3, 5456/4, 5457/1, 2&4, 5458/1-4; 5558/1, 2&4, 5559/1-4, 5659/1 2&4, 5660/3, 5761/1
	AMS CALL NO.: 80M 23-30-56605-25		Slovenjgradec/3a-d&4c-d, Maribor/3c-d, Durdevac/1a-c, Ptuj/1a-d&2a-c, Cakovec/1b-d, 2a-d
	AMS CALL NO.: 17M 3-30-49005-25		152/2-4, 153/1-4, 164/1&4S.N., 178/1-4, 179/2-4S.N., 180-181/1-4, 195/1-2, 196/1-4, 197/1&2, 198/1-3, 199-201/1-4

1-05 REFERENCES.

All references cited in this report are listed in the Bibliography following Section V of the text.

SECTION II
DRAINAGE BASIN CHARACTERISTICS AND DEVELOPMENTS

2-01 GENERAL.

a. The DRAU (DRAVA) River is one of the principal right-bank tributaries of the DANUBE River. The total length is 724 km. The DRAU River rises in the Tyrolean Region of the ALPS and flows generally eastward to join the DANUBE River at Km 1384 above its mouth. In the upper Alpine reaches, the river closely parallels the southern border of AUSTRIA. It enters YUGOSLAVIA near DRAVOGRAD (UNTERDRAUBURG) (Km 136) and forms the border between YUGOSLAVIA and HUNGARY from the mouth of the MUR (MURA) River (Km -55) to DONJI MIHOLJAC (Km -190). There, the frontier diverges to the north, and the river flows east-southeast through Yugoslavian territory to the DANUBE River. The principal left-bank tributaries are the ISEL, MOELL, GURK, LAVANT, and MUR Rivers. Stream tributaries on the right bank include the GAIL, DRAVINJA, BEDNJA, KARAŠICA, and VUZICA Rivers.

b. The MUR (MURA) River is the largest tributary of the DRAU River. It originates in the CENTRAL ALPS of AUSTRIA and flows east-northeast for about 200 km to the junction of the MÜRZ* River (Km 235), then turns sharply southward. Near GRAZ the river turns southeast to join the DRAU River near LEGRAD (DRAU River Km -55). The total length is 455 km. The upper 325 km lies entirely in AUSTRIA; the portion between Km 130 and Km 96 serves as the Austrian-Yugoslavian border; the reach between Km 96 and Km 41 lies in YUGOSLAVIA; and the lower 41 km serves as the boundary between YUGOSLAVIA and HUNGARY. Principal tributaries include the POIS, LIESING, and MUERZ Rivers on the left bank and the GRANITZEN and KAINBACH Rivers on the right bank.

c. The lower 148 km of the DRAU River provides for limited navigation; none of the other streams in the basin are considered navigable. Numerous hydroelectric plants are located on the DRAU and MUR Rivers and their tributaries. Important highway and railway lines follow and cross the stream valleys of the mountainous DRAU River basin. A general map of the area is presented as Plate 1 and detailed description is contained in Exhibits A and B of this report and in the documents listed in the Bibliography as References 1 to 10, inclusive.

2-02 TOPOGRAPHY.

The DRAU River rises in the rugged terrain of the TYROLEAN ALPS. At MARIBOR (Km 72) it leaves the ALPS, and at PTUJ (Km 44) the river begins to spread and meander over a wide area, forming many islands and dividing into multiple channels. The topography of the MUR River is similar to that of the DRAU; the upper reaches traverse rugged Alpine terrain and the lower part below GRAZ (Km 179) flows through a wide flat valley. Those two rivers are the only major streams flowing eastward from the central Alpine region through the exterior Alpine mountain range, the "Steirische Rand Gebirge." Plate 2 is a

*Also spelled as MUERZ

physiographic diagram illustrating the general nature of the topography; Exhibits A and B and References 6 through 14 contain detailed topographic description of the region.

2-03 GEOLOGY.

The upper reaches of the DRAU and MUR Rivers lie in deep glaciated troughs, containing many flat-floored silted basins and steep rock terraces. The general course of the upper DRAU River lies along the contact of crystalline with limestone rocks; hence the geologic structure is complex and variable. The lower reaches of the river in the flat plains is characterized by coarse rubble and gravel stream-bed and banks. Here the channel and banks are subject to considerable shifting. Detailed descriptions of the geology of the area are contained in Exhibits A and B and in References 5 through 14.

2-04 DRAINAGE AREAS.

The total drainage area of the DRAU River is 40,131 km^2, of which 14,412 km^2 is drained by the MUR River. This may be compared with the 95,000 km^2 drained by the SAVA River. The drainage area of the DANUBE River above the confluence of the DRAU River is approximately three times that of the DRAU River. Table 3 lists drainage areas at key gaging stations. A tabulation of drainage areas as listed in Reference 15 for major streams in the DRAU River basin follows:

River	Location	Drainage Area (km^2)
ISEL	Mouth	1,203
MOELL	do	1,104
LIESER	do	1,037
GAIL	do	1,403
GURK	do	2,584
LAVANT	do	969
MUR	do	14,412
DRAU	Above MOELL R.	3,673
do	Above GURK R.	7,824
do	Above LAVANT R.	11,052
do	Mouth	40,131

2-05 GRADIENTS AND PROFILES.

Stream gradients are steep in the upper mountainous regions upstream from the confluence of the DRAU and MUR Rivers, and more gradual in the lower reaches as may be seen on the general profile on Plate 3 and the stream profiles of Plates 4a to 4e. A tabulation of average gradients on the DRAU and MUR Rivers follows:

Reach	River Km	Average Gradient m/km
DRAU R.		
SILLIAN-LIENZ	400 to 369	12.8
LIENZ-MARIBOR	369 to 72	1.4
MARIBOR-BARČS	72 to-111	0.8
BARČS-DANUBE R.	-111 to-262	0.15
MUR R.		
ST. MICHAEL-FROHNLEITEN	297 to 210	7.3
FROHNLEITEN-WILDON	210 to 155	1.9
WILDON-DRAU R.	155 to 0	1.0

2-06 CHANNEL DEPTHS.

At mean water, depths in the DRAU River range from about 1.5 m near LIENZ to 3.0 m near PTUJ, and decrease to slightly over 2 m in the lower reaches downstream from BARČS. At mean high water (MHW), depths are 2 to 3 m deeper. During low water, depths are approximately 1 m lower than at mean water, except within the pools above the power dams. Numerous shoals exist in the lower reaches of the river. The depth of the MUR River ranges from about 0.5 to 1.5 m at low water, 1 to 2.5 m at mean water, and 3 to 5 m at high water. Depths in that stream are greatly influenced by the operation of the numerous small power dams and weirs. Reference is made to the depth profile on Plate 5 and to References 2 and 9 for additional information on river depths. A tabulation of representative average depths along the DRAU River follows:

Reach	River Km	Depth at MW (m)	Depth at MHW (m)
LIENZ-MARIBOR	369 to 72	1.5 - 2.5	3.5 - 5.0
MARIBOR-BARČS	72 to-111	1.5 - 3.0	4.0 - 5.0
BARČS-DANUBE R.	-111 to-262	2.0 - 2.5	3.5 - 5.0

2-07 CHANNEL AND FLOOD-PLAIN WIDTHS.

The channel of the DRAU River is narrow in the upper reaches, averaging from about 50 to 100 m. In the lower reaches the channel width varies from 100 to 250 m, although the total distance across the divided stream branches and meanders often reaches several kilometers. In the upper reaches, the flood-plain includes the flat bottoms of the basins and extends from 100 to 1,000 m from the stream banks. Along the flat plains in the lower reaches, extensive areas up to nearly 10 km wide are subject to frequent and prolonged inundation as described in References 7 and 8.

2-08 NAVIGATION.

The DRAU (DRAVA) River is the only navigable stream within its basin. Navigability on the DRAU River ceases at BARČS (148 km above the

DANUBE River confluence); although OSIJEK, 19 km above the mouth, is generally considered the limit for regular Danube craft. Although the navigable section has no important tributaries, there are many short streams. Numerous shoals, water mills, shifting channels, and islands make navigation hazardous. Only shallow-draft vessels can negotiate the river as far as BARČS. There are no locks, dams or aqueducts on the navigable section of the DRAU River. Ice formations last a maximum of 60 days, although there have been ice-free winters. Normally, ice begins to form around the end of December; the average break-up date is 10 February. Detailed information is contained in References 1, 2, 3, 16 and 17.

2-09 REGULATION.

The numerous hydroelectric power dams and reservoirs located in the DRAU River basin do not provide sufficient storage for significant regulation of water for flood-control, irrigation, or navigation. The Yugoslavian authorities have complained that Austrian hydroelectric developments have deprived downstream projects of sufficient water for power generation. Some attempt has been made to improve navigation and reduce flood damages by dredging, channel rectification, bank revetments, and levees along the lower reaches of the DRAU River.

2-10 DAMS AND RESERVOIRS.

a. Reservoirs. The natural lakes described in paragraph 2-13a contain considerable water. The largest, MILLSTAETTER SEE holds 1228 million m^3. However, since the lake bottoms are much lower than the outlet elevations, only a small amount of the stored water may be utilized for stream regulation or power development. Most of the artificial reservoirs are connected with "run-of-the-river" power projects, and consequently have limited storage capacity. The pools of the six DRAU River dams located between SCHWABECK (Km 153) and MARIBOR (Km 76) are perhaps the largest and most important. Their combined storage capacity is slightly over 100 million m^3. Reservoir storage volume is summarized in the table of data on hydroelectric structures, Table 4. Reference is made to Exhibits A and B for detailed descriptions of existing and proposed reservoirs.

b. Hydroelectric Dams. Numerous hydroelectric projects are located on the DRAU and MUR Rivers and on their mountainous tributaries. Several are large structures, although most are less than 10 m high. Locations of major projects are shown on the general map, Plate 1, and a summary of available data on major hydroelectric projects is presented as Table 4. Locations of dams on the DRAU and MUR Rivers also appear on the stream profiles, Plates 4a to 4c. Exhibits A and B contain descriptions of important power developments as translated and abstracted from technical literature listed as References 12 to 14 and 18 to 39 in the Bibliography. Additional information may also be found in References

2-10

40 to 46, inclusive. Reference 47 contains detailed data on Austrian electric power projects; presently available supplements cover projects listed in Table 4 of this report as Serial Nos. 1, 2, 7 to 12, and 14. This study was concentrated on the artificial flooding potentialities afforded by the six DRAU River dams between SCHWABECK (Km 153) and MARIBOR (Km 76), and the three dams in the TEIGITSCH River developments on a tributary of the KAINBACH in the MUR River basin near GRAZ. These dams are designated as Serial Nos. 1 to 8, inclusive in Table 4 and on Plate 1. (See description in Exhibits A and B). These dams are now all in operation with the exception of the DRAU River VUZENICA (Km 124) power plant which is under construction. Sketches of the dams considered in this study appear on Plates 9a to 9d. A tabulation of pertinent data on the dams considered in this study follows:

Dam	River Km.	Storage ($10^6 m^3$)	Dam Height (m)	Gates
DRAU RIVER				
SCHWABECK	153	25.0	22	4 @ 18.75x14
LAVAMUEND	147	6.8 (e)	11	4 @ 24x11
DRAVOGRAD	136	11.0 (e)	17	4 @ 24x11
VUZENICA	124	19.0 (e)	18 (e)	4 @ 18.75x14 (e)
FALA	92	16.7 (e)	18	5 @ 15x15
MARIBOR	76	27.0 (e)	18	4 @ 18.75x14
TEIGITSCH RIVER				
PACK	222*	5.41	29	—
HIERSMANN	211*	7.3	58	—
LANGMANN	209*	0.3	26	—

(e) Estimated
* Above mouth of MUR R.

c. Navigation Locks and Dams. There are no navigation locks or dams on the DRAU River or its tributaries.

d. Mill Dams. Many small mill dams are located in the upper reaches of the streams of the DRAU River basin, especially along the MUR River. They include millraces and supply canals and store small amounts of water for local industrial power use.

2-11 LEVEES.

A number of short low levees have been built to provide flood protection for farmland and local communities along the flat lower reaches of the DRAU River and in the so-called "polje" or basins of the upper reaches. There is no complete integrated levee system along the DRAU River. Levees and bank revetments extend along practically the entire 350 km stretch of the MUR River located in Austrian territory. However, only local levees have been built along the Yugoslav and Hungarian portion of the MUR River. No accurate recent data were available concerning the height and extent of levee systems in the area.

2-12 CANALS.

The DRAU River basin does not have any navigation canals. Many short small canals divert water from the streams for local use and power generation. Some short irrigation and drainage canals exist in the flat basins and plains along the DRAU River.

2-13 LAKES, PONDS, GLACIERS AND MARSHES.

a. Lakes. A number of deep lakes are located in glaciated valleys along the upper reaches of the DRAU River. The lake bottoms lie much lower than the outlets, which are mostly small streams. Consequently, only a limited part of the lake storage can be released. Some of the lakes are utilized in connection with hydroelectirc power developments, as discussed in paragraph 11 of Exhibit A. The area and volume of a few of these major lakes as given in Reference 13 are as follows:

Lake (See)	Area (km^2)	Volume (million m^3)	Maximum Depth (m)	Mean Depth (m)
WOERTHER	19.5	840	84.6	43.2
MILLSTAETTER	13.3	1223	140.7	86.5
OSSIACHER	10.6	201	46.0	19.0
WEISSEN	6.6	202	99	33.5
FAAKER	2.3	33	30	14.2
KEUTSCHACHER	1.3	13	15	9.4

b. Glaciers. The topography of the DRAU River basin is in large measure a result of glacial action. A number of glaciers still exist at high elevations on the headwaters of the left bank tributaries of the DRAU River. Melting of these glaciers tends to increase stream flow during periods of light rainfall and is an important source of water supply for several hydroelectric developments. In recent times the glaciers have receded as described in References 12 and 13. A tabulation listing a few important existing glaciers follows:

Stream Headwater	Glacier	Height of Tongue (m.u.A.)	Area (hectares) 1860	1930
MOELL R.	PASTERZE	1970	3196	2433
	KLEINELEND	2170	540	250
	GROSSELEND	2220	576	517
ISEL R.	SCHLATEN	1940	1181	1127
	UMBAL	2225	837	733

c. Ponds and Marshes. In the upper reaches of the DRAU River are a number of wide flat valleys such as the KLAGENFURT BASIN. Those basins have been eroded by glacial action and were formerly lakes until

the river eroded an outlet. These basins now contain significant marshy areas. Many other extensive swampy areas lie along the lower reaches of the DRAU and MUR Rivers. The lower DRAU River especially is subject to frequent meandering of its course, leaving many "cut-offs" or "ox-bow lakes," abandoned flood-stream courses and multiple channels. These create low-lying pockets many of which contain ponded water or swampy bottomland. Much of the flat lowland in the "PODRAVINA" region along the lower DRAU River is subject to inundation during much of the year. Reference is made to Exhibits A and B and to References 6 and 7 for additional information.

2-14 BRIDGES.

Reliable information concerning post-war bridges was not available in this office; however, locations of important bridges as taken from maps are indicated on the river profiles, Plates 4a to 4e.

SECTION III
HYDROLOGIC CHARACTERISTICS

3-01 GENERAL.

a. Information regarding river stage, discharge, flow duration and velocity are presented in generalized graphical form insofar as practical to facilitate application of the data to specific military problems. The cited references should be utilized for supplementary data.

b. Available hydrologic records for the Austrian portion of the DRAU (DRAVA) River basin are fairly complete, except for the period between 1934 to 1947. Publication of records for that period has been delayed because of the war. Available hydrologic records for the Yugoslavian and Hungarian portions of the basin are scanty and incomplete. Continuity of records has been hindered by the frequent political and territorial changes in the region.

3-02. CLIMATOLOGY.

The climate of the DRAU River basin is mainly of the continental type. Generally, rainfall is greatest during the summer, especially in the mountainous regions. Snow cover is heavy in the mountains and melts during the spring, creating flood conditions in May and June. The streams in the highlands freeze during extreme winters only in those spots where stream velocity is low; those in the lowlands sometimes freeze for a maximum of 60 days between December and March. Rainfall records for AUSTRIA are published in Reference 48; records for YUGOSLAVIA are published in Reference 49. Additional information on climate may be found in References 12, 13 and 50 through 53. The seasonal variation in precipitation is illustrated by the following tabulation based on data in References 50 and 53:

MEAN MONTHLY PRECIPITATION (Inches)

	KLAGENFURT 46°37'N 14°18'E	GRAZ 47°04'N 15°28'E	CAKOVEC 46°23'N 16°26'E	OSIJEK 45°33'N 18°42'E
Jan	1.3	0.9 Min.	2.0	1.3
Feb	1.2 Min.	1.0	1.5 Min.	1.2 Min.
Mar	2.2	1.7	2.6	1.6
Apr	2.6	2.7	3.4	2.4
May	3.5	3.1	3.5	3.0
Jun	4.5	4.7 Max.	4.3	3.1 Max.
Jul	4.6	4.6	3.9	2.4
Aug.	5.0 Max.	4.5	4.1	2.3
Sep	4.3	3.4	3.7	2.2
Oct	4.6	3.2	4.4 Max.	2.5
Nov	2.6	1.8	2.6	2.0
Dec	1.9	1.3	2.2	1.7
Year	38.3	32.9	38.2	25.7
Years of Record	-	-	49.	29.

3-03 STREAM GAGING STATIONS.

A number of stream gages have been established on the DRAU River and its tributaries. Stage records and other data for the more important Austrian stations may be found in References 48 and 51, and for Yugoslavian stations in References 54, 55 and 56. Locations of key stations are shown on the General Map, Plate 1, and on the stream profiles, Plates 4a to 4e. Pertinent gage data extracted from the above references are summarized in Table 3.

3-04 RIVER STAGES.

a. Records. The mean and extreme stages of record are tabulated in Table 3. The data shown were extracted from sources listed in previous paragraph 3-03 and cover various periods of record. As indicated in Table 3, gage locations and gage zeros were often changed. Stages recorded in various yearbooks are referenced to different gage zeros. Care should be exercised in comparison of stages so that proper gage zeros are used. The effect of normal operation of the hydroelectric dams is believed to be slight as most of them are "run-of-the-river" plants and do not store large quantities of water.

b. Stage Variation. Seasonal stage variation is illustrated on the graphs of mean monthly stages presented on Plates 6a to 6c. The winter stages are low due to light precipitation and to retention of snow in the mountains; melting of snow and ice produces high stages during the spring months of May and June. In most cases this is followed by a short period of low stages, but the heavy summer rains again produce high stages during July and August, often lasting until the start of the autumn drought period in September or October. The double seasonal cyclic stage variation is not as pronounced in the DRAU Basin as in the SAVA River basin to the south. As indicated on the depth profile, Plate 5, mean high water (MHW) stages average from 2 to 3 meters higher than mean water (MW) stages. Mean low water (MNW) averages about 1 m below mean water (MW) stages. The ranges between high and low stages at representative stations on the DRAU and MUR Rivers are shown in the following tabulation:

Stream	Station	River Km	Range of Stage (m) HHW-NNW	Range of Stage (m) MHW-MNW
DRAU R.	LIENZ	369	2.9	2.0
	VILLACH	257	6.0	3.1
	PTUJ	44	5.5	2.4
	ORMOZ	12	3.8	3 (est.)
	BOTOVO	-63	5.6	4 "
	D. MIHOLJAC	-190	5.1	4 "
MUR R.	ST. MICHAEL	297	4.3	No data
	FROHNLEITEN	210	3.8	" "
	WILDON	155	4.4	" "
	RADKERSBURG	101	4.1	" "

3-04

c. Stage Duration. Stage duration curves for several key stations on the DRAU and MUR Rivers are shown on Plates 7a and 7b. These curves show the percent of time that a given stage may be expected to be equalled or exceeded. Those for Austrian stations were derived from discharge duration curves given in Reference 14; those for Yugoslavian stations were taken from stage duration curves given in Reference 55. The median stage (that equalled or exceeded 50 percent of the time), shown on Plates 7a and 7b, should not be confused with the mean stage (an arithmetical average) given in Table 3. Comparison of representative median and mean stages follows:

Stream	Station	River Km	Stages (cm) Mean (MW) (Table 3)	Median (Plate 7)
DRAU R.	MARIBOR	73	108	100
MUR R.	FROHNLEITEN	210	222	215

3-05 RIVER DISCHARGES.

a. Records. Available official published records of river discharges for streams in the DRAU River basin are scanty and incomplete. The discharge data summarized in Table 3 and shown on the discharge profile of Plate 5 represent estimates derived by application of the published stage data to the stage-discharge relation curves described in the next sub-paragraph.

b. Stage-Discharge Relation. Average stage-discharge rating curves for key stations in the DRAU River basin are presented on Plates 8a to 8d. These curves were estimated from the scanty observed discharge measurements and equivalent stage-discharge statistical data contained in References 48, 51 and 55.

c. Discharge Variations. Stream discharge follows the same seasonal pattern of variation as the stage. (See paragraph 3-04b). Estimates of mean and extreme discharges are included in Table 3 for stations where data were available. The profile of mean (MQ) and mean high (MHQ) discharge illustrates the manner in which discharge increases as one progresses downstream. The following tabulation summarizes mean and maximum discharges at representative key stations on the DRAU River:

Station	River Km	Discharge (m^3/sec) Mean MQ	Period	Maximum HHQ	Date
LAVANT	362	42	1924-30	800	14-9-03
VILLACH	257	150	1924-33	1900	2-11-51
NEUBRUECKE	185	280	1924-33	2400	13-10-89
MARIBOR	73	340	1923	2600	15-9-03
D. MIHOLJAC	-190	650	1926	3000	11-3-91

d. Discharge Duration. The percent of time that a given discharge may be expected to be equalled or exceeded is shown on the duration curves of Plates 7a and 7b. These curves were derived as discussed in paragraph 3-04c.

3-06 RIVER VELOCITIES.

a. General. The velocity of stream flow varies according to the conformation of the river bed, depths, obstructions, restrictions, local variation of slope, etc. Channel improvements and cutoffs, training walls and levees, operation of dams and other modifications of natural conditions appreciably affect the stream velocity. Influent rivers in flood tend to elevate the main river waters at the point of confluence. Accordingly, correlations between river stages and surface velocities at gaging stations cannot be interpreted as applicable to all points along the adjacent river sections, but only serve as general indications.

b. Surface Velocities. Insufficient basic information concerning the hydraulic characteristics (cross-sectional area, wetted perimeter, water surface slope, roughness factor, etc.), was available to permit accurate determination of stream velocities. Estimates were based on velocities observed during discharge measurements at gaging stations as recorded in References 48, 51 and 55, and on average velocities given in References 2, 5, 9 and 10. The recorded velocities were assumed to be mean cross-sectional velocities, and were increased by 18 percent to indicate the mean surface velocities. As indicated in the velocity studies described in Reference 57, the mean cross-sectional velocities should be increased by 25 to 75 percent to obtain the maximum surface velocities likely to be encountered during crossing operations. Estimated mean surface velocity ratings at the gaging stations are presented on Plate 8. Velocity profiles at MW and MHW appear on Plate 5. Mean surface velocities at selected stations on the DRAU River for mean water (MW) and mean high water (MHW) conditions are tabulated below to indicate the general trend of stream velocities:

Station	Km	Mean Surface Velocities (m/sec) MW	MHW
OBERDRAUBURG	350	1.6	3.0
FEISTRIZ	278	1.8	3.6
ROSEGG	239	1.8	2.6
NEUBRUECKE	185	1.8	3.1
MARIBOR	73	2.0	3.0
PTUJ	44	2.4	3.0
BARCS	-111	2.6	3.9
D. MIHOLJAC	-190	1.0	1.2

3-06

c. Flood Wave Travel Time. Examination of flood crest times of 27 natural floods that occurred during the period from 1903 to 1932, as recorded in the official Austrian Hydrologic Yearbooks (Reference 48) revealed considerable variation in rate of travel of various flood peaks. An estimated average rate of travel of natural flood waves on the DRAU River derived from those floods, follows:

DRAU RIVER, REACH	River Km	Average Travel Rate of Peak (km/hr)
ISEL R. - MOELL R.	340 to 310	13
MOELL R. - GAIL R.	310 to 250	11
GAIL R. - GURK R.	250 to 190	9
GURK R. - LAVANT R.	190 to 140*	8*
LAVANT R. - PESNICA R.*	140 to 13	7*

*Operation of the DRAU River dams (Serial Nos. 1-6), built since 1938 between SCHWABECK (Km 153) and MARIBOR (Km 76) would alter flood wave travel downstream from those structures.

SECTION IV
ARTIFICIAL FLOODING POTENTIALITIES

4-01 GENERAL.

a. The term "artificial flood" as used in this report applies to any major increase in the extent of flooding, over that normally prevailing with existing developments, that is brought about by manipulation of control structures, breaching of dams or levees, or temporary damming operations designed to create flooding conditions. Applications of artificial flooding considered in this report fall into the following four general categories:

(1) Still-water barriers, created by flooding land to form water obstacles, using such means as breaching levees, diverting flow from canals, raising crests of existing dams or constructing temporary dams.

(2) Drainage obstacles or mud-flats, in which the wetness of the soil is increased to form muddy or marshy conditions that would impede military traffic, brought about by disrupting the normal drainage, destroying pumping and drainage facilities used to drain marshy or low land, or by inducing shallow inundation of flood-plains or reclaimed land. Mud-flats may also be formed by draining areas normally inundated by reservoirs or ponds.

(3) Stream flow variations, in which changes in discharges, depths, velocities and widths of streams are brought about to hinder stream-crossing operations or navigation such as might be accomplished by opening and closing outlet works of water control structures.

(4) Major flood waves, created by sudden breaching of a dam to release large quantities of impounded water.

b. Certain opportunities exist for effective use of these artificial floods in the DRAU (DRAVA) River basin. This section presents a review of the potentialities and a quantitative evaluation of the hydraulic effects. Reference should be made to Section V for discussion of associated military factors.

c. Brief estimates of artificial flooding possibilities by British, German and Hungarian military sources are included in the documents listed in the Bibliography as References 7, 9, 10, and 58.

4-02 STILL-WATER BARRIERS AND DRAINAGE OBSTACLES.

a. General. The studies reviewed in this paragraph pertain to artificial flooding produced by creation of still-water barriers and drainage obstacles along the DRAU and MUR Rivers. The studies were

largely based on a map study using 1:50,000 maps of the G.S.G.S. 4229, 4529 and 4734 series. Exact determination of elevations, contours and boundaries from these maps was difficult; however, the results of this study are believed to offer good indications of the relative possibility of such flooding. First hand information should be obtained by local reconnaissance regarding ground elevations and the locations, elevations, and dimensions of levees, roadfills, and culverts in the vicinity of specific barriers in order to accurately establish the area subject to artificial flooding.

b. Hydrologic Considerations.

(1) The effect of artificial flooding is largely contingent upon the natural hydrologic conditions prevailing at the time of the operation. The volume of water stored and available within the basin, the stream discharge and the river stage are important factors influencing the effectiveness of still-water barriers. Reference is made to Section III of this report for detailed description of hydrologic characteristics of the basin and to Section II for description of physical features such as stream and reservoir dimensions.

(2) Attention is directed to the wide range between high and low stream flows shown in Table 3 and on Plate 7 and discussed in paragraph 3-05. The following mean natural discharges were used in this study to estimate the average stream flow available for supplying water for still-water barriers and drainage obstacles:

River	Reach	Average Mean Discharge (m^3/sec)
MUR	RADKERSBURG - DRAU R.	125
DRAU	VILLACH - GURK R.	200
	MARIBOR - VARAZDIN	300
	VARAZDIN - BOTOVO	500
	BOTOVO - D. MILHOLJAC	600

c. Means of Creating Still-Water Barriers and Drainage Obstacles.

(1) The water obstacle afforded by the natural streams in the DRAU and MUR River basins could be increased by utilization of one or more of the following means:

(a) Creation of still-water barriers by construction of temporary dams at bridge sites, combined with closing of culverts and other openings in levees and road fills.

(b) Inundation of lowlands along the streams by breaching dikes and levees and opening of flood gates in levees.

(c) Inundation of lowlands by closing normal drainage outlets.

(2) Increasing the pool height of the existing hydro-electric power dams and weirs located on the DRAU and MUR Rivers would probably not appreciably increase the extent of the obstacle afforded by the upper pools at those structures, due to the steep stream gradients and high banks prevailing at the location of those dams.

(3) In order to obtain quantitative evaluation of the potential artificial flooding at various locations, analyses were made on barriers resulting from temporary damming to heights of 2 to 9 meters above mean water (MW). The assumed heights of the temporary dams were established at the minimum elevation that would produce significant still-water barriers. In this study, it was assumed that the surface of the pools above the temporary dams would be level and that mean water conditions would prevail at the time of the operation. During high water conditions, greater flooding could be expected due to the increased slope of the water surface upstream from the temporary dams.

d. Effect of Still-Water Barriers.

(1) General. The effects of artificial flooding created by temporary damming operations on the DRAU and MUR Rivers are summarized in Table 5 and the extent of inundation indicated on Plates 10a and 10b. Potential drainage obstacle sites are indicated in the notes of Table 5 and the locations and approximate extent shown by symbol on Plates 10a and 10b. The flooding produced by temporary damming operations would cover isolated areas ranging from 2 to 7 km long and from 0.5 to 7 km wide. Formation of continuous overbank flooding by means of temporary dams is not considered practicable in this area. Insufficient topographic data were available to permit analysis of the effects of blocking natural drainage along the MUR and DRAU Rivers; however, it appears that such disruption of natural drainage would considerably increase the extent of natural marshy and swampy areas along those rivers. Review of the effects of still-water barriers and drainage obstacles in specific reaches of the DRAU and MUR Rivers follows.

(2) DRAU River-LIENZ (Km 369) to VILLACH (Km 257). Above VILLACH the DRAU River generally flows through a steep narrow valley. The steep gradient, high banks and generally narrow valley floor make the creation of obstacles by temporary damming operations impracticable.

(3) DRAU River-VILLACH to GURK River (Km 188). At VILLACH the valley floor widens considerably. The banks in this reach are generally high; however, erection of a temporary dam to a height 5 m above mean water at the Road Bridge near KAPPLE, Site No. 1, (Km 212.5) would form a pool 2.5 km long and averaging 0.5 km wide. The swamps immediately south of KLAGENFURT could probably be utilized as a drainage obstacle by blocking the natural drainage of the GLANFURT, GLAN, and GURK Rivers in the area. As indicated on Plate 10a, this swampy area coupled with the WOERTHER SEE would form a continuous obstacle approximately 22 km long and roughly paralleling the DRAU River 7 to 10 km north of the left bank.

(4) DRAU River-Confluence of GURK River to MARIBOR (Km 72). Below the confluence of the GURK River the DRAU River enters a deep gorge. The steep walls and narrow floor of the valley makes the creation of still-water barriers in this reach impracticable. The pools of the SCHWABECK, LAVAMUEND, DRAVOGRAD, VUZENICA, FALA and MARIBOR power dams (Serial Nos. 1-6) form a practically continuous obstacle ranging in depth from 3 to 25 m, although the width averages only about 170 m.

(5) DRAU River-MARIBOR to D. MIHOLJAC (Km -190). Below MARIBOR the DRAU River enters a relatively wide valley. In this reach the river meanders considerably. At mean water, the river width varies from 100 to 200 m. As indicated in Table 5 and on Plate 10b, the effective width of portions of the river could be increased by blocking of the following bridges: the RR Bridge at PTUJ, Site No. 2, (Km 43.7); Road Bridge at ORMOZ, Site No. 3, (Km 13.3); RR Bridge at BARCS, Site No. 6 (Km -114); and the RR Bridge at Site No. 7, (Km -148). The resulting obstacle would largely be due to swamping of the areas between the meanders and to flooding of old meander beds. Overbank flooding could be created by operations at: VARAZDIN, Site No. 4, (Km -8.9); BOTOVO, Site No. 5, (Km -68); and D. MIHOLJAC , Site No. 8, (Km -190). As shown in Table 5 and on Plate 10b, the erection of a temporary dam at the Road Bridge in VARAZDIN, Site No. 4, to 2 m above mean water would form a barrier 4 km long and averaging 1 to 2.5 km wide. A temporary dam 9 m above mean water at the RR Bridge near BOTOVO, Site No. 5, would create a pool 6 km long and approximately 5 to 7 km wide. The barrier formed by a temporary dam with top elevation at 3 m above mean water at the RR Bridge in D. MIHOLJAC , Site No. 8, would be 5 km in length and 3-5 km in width. As shown on Table 5, these pools would be relatively shallow averaging 1 m or less in depth. The large swampy area north of the river between LEGRAD (Km -55) and BARCS, (Km -111) shown on Plate 10b, could probably be utilized to form an effective drainage obstacle.

(6) MUR River. From its source to RADKERSBURG (Km 101) the steep gradients and the generally narrow valley make the creation of still-water barriers by temporary damming operations impracticable. At the RADKERSBURG RR Bridge, Site No. 9, (Km 100.8), erection of a temporary dam to elevation 210 m.u.A. (MW+5.4 m), would create a still-water barrier approximately 7 km long and from 3 to 4 km wide. Between km 100 and km 50, the LEDAVA and DOBEL Rivers run in leveed sections parallel to and from 4 to 10 km north of the MUR River. The land lying between those rivers and the MUR River appears to be flat and is probably subject to flooding. In this section blocking of the RR Bridge near VERZEJ, (Km 81.2) and of the RR Bridge at MURSKO SREDISCE, Site No. 10, (Km 52.7) would probably cause considerable inundation. At the RR Bridge near KOBORIBA, Site No. 11, (Km 9.0) flooding of old meander beds for a distance of 3-4 km upstream from the bridge is possible by erecting a temporary dam 5 m above mean water (see Table 5 or Plate 10b). There do not seem to be any other suitable sites for significant still-water barriers along the MUR River.

c. Water Requirements of Still-Water Barriers.

(1) The volume of water required to effect the artificial flooding on the MUR and DRAU Rivers described in the preceding paragraphs and shown in Table 5 and on Plates 10a and 10b, together with the estimated time required for filling at the average mean rates of flow given in paragraph 4-02b, are approximately as follows:

Site No.	Location	Water Requirement (million m^3)	Approximate Filling Time (hrs.)
MUR River			
9	RADKERSBURG	18.0	40
DRAU River			
1	KAPPLE	1.5	2
4	VARAZDIN	8.0	5
5	BOTOVO	35.0	19
8	D. MIHOLJAC	20.0	10
		82.5	

(2) The water stored in the hydroelectric reservoirs of the basin (described in paragraph 2-10), could be used to supplement natural flow for filling of still-water barriers. The 100 million m^3 in the DRAU River SCHWABECK-MARIBOR group (Serial Nos. 1 to 6) would suffice for filling of still-water barriers on the lower DRAU River. That storage could be released in about 15 hours by opening the large weir gates. The flow would take about 2 days to arrive at D. MIHOLJAC, the farthest downstream still-water barrier.

(3) Although about 13 million m^3 of water are contained in the PACK, HIERSMANN and LANGMAN Reservoirs of the TEIGITSCH group (Serial Nos. 7 and 8), the dams would have to be breached in order to release the stored water in a reasonable time to supplement natural flow for filling of still-water barriers along the MUR River. The discharge of the bottom outlets of those structures is so small (less than 10 m^3/sec, as described in paragraph 5 of Exhibit B), that over a month would be required to empty the reservoirs. Exact data concerning the storage capacities and the outlet discharge capacities of the numerous small dams on the MUR River (shown on the general map, Plate 1, and on the stream profile, Plates 4d and 4e) are not available. However, the total storage probably does not exceed about 10 million m^3. By opening of the sluice gates in the weirs and canals, this water could be released to supplement natural stream flow in filling of the RADKERSBURG still-water barrier (Site No. 9) or other possible barriers on the MUR River or lower DRAU River shown on Plate 10b and listed in Table 5.

4-03 STREAM FLOW VARIATIONS.

a. General. The studies in this paragraph pertain to the artificial flooding that might be produced along the DRAU River by

release of water from the gated openings of the DRAU River hydroelectric power dams at SCHWABECK, LAVAMUEND, DRAVOGRAD, VUZENICA, FALA, and MARIBOR. Inasmuch as the area of the openings approach that producible by breaching of the structures, these "flow variations" might be considered as "major flood waves." However, in conformance with the definitions set forth in paragraph 4-01, these releases from the gated openings are considered as "stream flow variations" for purposes of this study. The flow variations may be repeated to produce cyclic effects, dependent upon replenishment of reservoir storage. Reference is made to paragraph 2-10 and Exhibit A for description of the dams, to Plate 1 for locations, to Plates 9a and 9b for sketches of the structures, and to Table 4 for summary of data. The dams are designated as Serial Nos. 1 to 6, inclusive. Insufficient data were available to permit similar studies of the effect of releases from the other hydroelectric projects listed in Table 4.

b. Hydrologic Considerations.

(1) The river stage and discharge existing at the time of release of flow from a dam greatly influence the effects. Natural flow conditions in the DRAU River vary considerably, as discussed in Section III and indicated on Plates 5 and 6. In this study, the assumed base flow in the river at the start of the artificial flow variations approximates mean water conditions.

(2) Reservoir storage also influences the effectiveness of flow releases. The pools might be expected to be full during the spring and summer, but possibly only partly full during the autumn and winter. Reservoir storage capacity curves, shown on Plates 11a and 11b were estimated from meager data contained in Exhibit A supplemented by topographic map information. In this study, two reservoir conditions were considered, namely:

(a) All six reservoirs full (including the incomplete VUZENICA dam).

(b) SCHWABECK reservoir full; the others assumed as being empty or destroyed.

(3) The possibility of cyclic releases from the reservoirs depends upon the rate of refilling of the depleted storage. Refilling of downstream dams can be facilitated by release of stored water remaining in upstream pools, if gates and structures are intact. Under normal mean flow conditions, the entire group can be refilled in about 4.5 days. A tabulation of estimated storage capacities and average filling times under mean water conditions follows:

4-03b(3)

Reservoir	Estimated Storage (million m^3)	Mean Inflow (m^3/sec)	Filling time (hrs.)
SCHWABECK	25.0	275	25
LAVAMUEND	6.8	"	7
DRAVOGRAD	11.0	"	11
VUZENICA	19.0	"	19
FALA	16.7	"	17
MARIBOR	27.0	"	27
TOTAL	105.5		106

(4) When flow overtops the stream banks, an appreciable volume of water is retained behind embankments and in depressions on the flood-plain and lost through evaporation, seepage, etc. For example, 39.5 percent of the water discharged from the EDER DAM breach of May 1943, was lost in the passage of the flood wave to INTSCHEDE, 426.6 km below the dam (see References 59 or 60). Consequently, in this study, it was assumed that for each 10 km of travel below MARIBOR (Km 76) 1 percent of the volume of discharge would be lost or retained on the flood plain. Since the reach between SCHWABECK and MARIBOR lies in a narrow valley with steep high banks and includes the reservoir area of the dams, it was assumed that volume losses would be negligible in that section of the river.

c. Means of Creating Detrimental Flow Variations. Sudden opening of one or more of the large gates of the DRAU River dams would produce detrimental flow variations in the DRAU River downstream from those structures. Plates 11a and 11b show estimated discharge capacity curves for the dams, based on hydraulic data contained in Exhibit A. A tabulation of discharges under normal pool conditions follows:

Dam	Normal Pool (m.u.A.)	All Gates Open: No. Gates	All Gates Open: Discharge (m^3/sec)
SCHWABECK	371.0	4	8500
LAVAMUEND	350.5	4	5500
DRAVOGRAD	341.5	4	5500
VUZENICA	333.5	4	8500
FALA	280.8	5	8000
MARIBOR	267.2	4	8500

d. Effects of Detrimental Flow Variations.

(1) General. The effects of detrimental flow variations produced by releases from the gated outlets of the six DRAU River dams are summarized in Table 6. The resulting discharge, depth, and velocity profiles of the crests of these releases are plotted on Plate 12 and representative stage hydrographs are shown on Plates 13a and 13b. The flow variations are designated for purposes of identification as follows:

4-03d(1)

Artificial Flood No.	Initial Dam Conditions	Gates Opened
1	All 6 dams full	All
2	do	One*
3	SCHWABECK full; others empty	All**
4	do	One**

*One of four gates opened at all dams, except FALA where two of five gates were considered opened.
**At SCHWABECK; all gates at other dams assumed as completely open or destroyed and the reservoirs empty.

(2) Artificial Flood No. 1 involves sudden full opening of all gates in the six dams, when all the reservoirs are full and an initial base flow of 275 m^3/sec is passing through the system. In order to achieve maximum effect, it was considered that SCHWABECK, LAVAMUEND, DRAVOGRAD and VUZENICA gates are opened simultaneously and that the opening of FALA and MARIBOR gates are delayed 2 hours after the opening of the upper four dams. The resulting peak discharge of 9500 m^3/sec at MARIBOR (Km 76) would cause an increase of 1940 m^3/sec over base flow at D. MIHOLJAC (Km -190), 266 km below that dam. River stages would be increased 2.9 m at D. MIHOLJAC as shown on the profiles of Plate 12 and summarized in Table 6. The stage profile is also plotted on the DRAU River stream profile, Plates 4b and 4c.

(3) Artificial Flood No. 2 represents the variation resulting from opening of a single gate at each of the dams (except at FALA where 2 gates were considered opened). Similarly to Flood No. 1, initial full pool conditions were assumed for all reservoirs as well as simultaneous opening of the four upstream dams. However, the delayed opening time for the lower two dams was taken as 4.5 hours in order to achieve maximum effectiveness. The peak discharge at MARIBOR would be 2550 m^3/sec, and the peak at D. MIHOLJAC would be 1040 m^3/sec greater than initial base flow at that place. Stages there would be raised 2.0 m as compared to 2.9 m for Flood No. 1. The duration of Flood No. 2 would range from 15 to 40 hours as compared to 4 to 20 hours for Flood No. 1. Comparative effects may be seen in Table 6 and on Plate 12.

(4) Artificial Flood No. 3 shows the effect of sudden opening of all SCHWABECK Dam gates under full pool conditions in that reservoir, but considering that the other five downstream dams are empty and completely opened or destroyed. In this event, the peak discharge of 8500 m^3/sec from the SCHWABECK gates would be reduced to 1800 m^3/sec at MARIBOR and would produce only 400 m^3/sec increase in discharge or 1.0 m increase in stage above base flow conditions at D. MIHOLJAC, as compared to 1940 m^3/sec and 2.9 m for Flood No. 1 at that location. This illustrates the influence of reservoir storage volume. Reference is made to the summary of effects in Table 6 and to the depth, velocity, and discharge profiles of Plate 12.

4-03d

(5) Artificial Flood No. 4 differs from Flood No. 3 in that only one of the four SCHWABECK gates was considered as being opened, other initial conditions being the same as in that flood. The peak discharge of 2125 m^3/sec at SCHWABECK would result in a peak flow of 1200 m^3/sec at MARIBOR. This would result in an increase over base flow conditions at D. MIHOLJAC of 400 m^3/sec, identical to the peak discharge of Flood No. 3 at that place. This indicates that the influences of the volume of discharge and of the channel characteristics become progressively more important factors than the size of opening as the flow travels farther downstream from the point of initial discharge. Table 6 and Plate 12 also show that the increase in discharge and depth created by this flood are approximately one-half to three-quarters as great as those created by Flood No. 2, in which all reservoirs were considered as being full.

e. Comparison of Effects of Flow Variations. As indicated in Table 6 and Plate 12, release of water from the gated outlets of the DRAU River Dams would result in significant increase of discharge, stage, and velocity in the reaches upstream of BARCS, 187 km downstream from MARIBOR. The increase would become progressively less in the lower reaches downstream from that location. A similar pattern may be ascertained regarding the width and depth of overbank flooding. However, in all cases, an extensive area near the confluence of the DRAU and DANUBE Rivers would probably be subjected to shallow overbank inundation. Maximum results would be attained by opening all the gates of the entire group of dams, when all reservoirs are full. Partial gate opening (such as opening of a single gate as in Flood No. 2) would still produce significant results; although the extent of overbank flooding would be appreciably reduced. Opening of one or more gates in SCHWABECK Dam, when the other reservoirs are empty (as assumed in Floods No. 3 and 4), would produce results slightly less than those produced by partial gate opening when all reservoirs are full (as in Flood No. 2). Peak values for the various conditions are summarized in Table 6. The relation of the various artificial flow variations are graphically illustrated on Plate 12. Extracts of pertinent effects from Table 6 at selected key locations are presented below to facilitate comparison between the various flow variations:

	Peak Values				
Flood No.	Depth m	Width Flooded km	Overflow height m	Mean Surface Velocity m/sec	Duration above Base Flow hr
At ORMOZ (Km 12)					
1	7.5	2-5	4.5	3.3	13
2	4.9	2-5	1.9	3.1	32
3	4.3	2-4	1.3	3.0	8
4	3.7	2-4	0.7	2.8	20
At D. MIHOLJAC (Km -190)					
1	4.8	0.5	Bankfull	1.1	18
2	3.9	0.5	Bankfull	1.1	38
3	2.9	0.5	Within banks	1.1	13
4	2.9	0.5	Within banks	1.1	22

4-04 MAJOR FLOOD WAVES.

a. General. The studies described in this paragraph pertain to artificial flooding that might be produced along the lower reaches of the MUR and DRAU Rivers by breaching of the PACK and HIERSMANN Dams (Serial Nos. 7 and 8) of the TEIGITSCH River hydroelectric power group. Reference is made to paragraph 2-10 and to Exhibit B for description of those structures. The "flow variations" produced by sudden opening of the large gates of the six DRAU River dams might also be considered as "major flood waves" as described in paragraph 4-03. Insufficient data were available to permit studies of the effects of major flood waves from other existing dams in the area. However, their effect might be expected to be local and of minor significance due to the small storage volume of most of the reservoirs or their location in the upper head-waters of the basin as indicated in Table 4 and Exhibits A and B.

b. Hydrologic Considerations.

(1) Reference is made to paragraph 4-03b for discussion of the influence of natural stream flow, initial reservoir storage and flood wave volume loss on artificial flood effects.

(2) For pusposes of this study, it was assumed that PACK and HIERSMANN reservoirs were at maximum full pool conditions. Since the capacity of the third reservoir in the TEIGITSCH group, the LANGMAN Dam is comparatively small (0.3 million m^3), its effect would be slight. Consequently, it was considered that it was empty and destroyed for purpose of this study. Likewise, the small MUR River dams were considered as empty and open. Reservoir storage curves for PACK and HIERSMANN Dams as computed from data contained in Exhibit B are shown on Plate 11b. A tabulation of storage capacities follows:

Reservoir	Pool Elevation (m.u.A.)	Storage (million m^3)
PACK	867.7	5.41
HIERSMANN	708.0	7.2

c. Means of Creating Major Flood Waves. Coordinated breaching of PACK and HIERSMANN Dams would produce flood waves of considerable magnitude in the TEIGITSCH and WAINBACH valleys and of limited magnitude in the reaches of the MUR and DRAU Rivers downstream from those damsites. For purposes of this study, the breach openings were assumed to be of trapezoidal shape, with side slopes of 2 vertical on 1 horizontal. Two sizes of openings were considered; one with a bottom width of 10 m, and the other with a 20 m bottom width. In both cases, the bottom of the breach was considered as lying 20 m lower than the elevation of the highest normal pool elevation (see Plate 11b). As indicated by the results of this study, larger size breach openings would not appreciably increase the magnitude of the flood waves on the MUR or DRAU Rivers.

Reference is made to the sketches of the structures on Plate 9d, the description in Exhibit B, and the breach discharge rating curves on Plate 11b. In order to outline the maximum probable effects, it was considered that both dams were breached with the same sized openings, and that the breaching of HIERSMANN Dam was lagged 0.3 hours after the breaching of PACK Dam.

d. Effects of Major Flood Waves.

(1) General. The effects of artificial flood waves on the MUR and DRAU Rivers produced by coordinated breaching of PACK and HIERSMANN Dams are summarized in Table 6. A graphical comparison of the discharge, depth, and velocity on the DRAU River resulting from these floods and from the flow variations created by releases from the six DRAU River dams (described in paragraph 4-03) is afforded on Plate 12. Representative stage hydrographs appear on Plate 13. The major artificial flood waves are designated for purposes of identification as follows:

COORDINATED BREACHING OF PACK AND HIERSMANN DAMS

	Artificial Flood No. 5	Artificial Flood No. 6
Bottom width of breaches (m)	10	20
Depth of breaches (m)	20	20
Breach side slopes	2 on 1	2 on 1
Pool Elev. (PACK) (m.u.A.)	867.7	867.6
Breach Elev. (PACK) (m.u.A.)	847.7	847.7
Pool Elev. (HIERSMANN) (m.u.A.)	708	708
Breach Elev. (HIERSMANN) (m.u.A.)	688	688
Peak discharges (m^3/sec)	2550	4050

(2) Artificial Flood No. 5 would result from trapezoidal breaches of 10 m bottom widths and 20 m depths at PACK and HIERSMANN Dams, with the breaching time of the latter lagged 0.3 hours after the breaching of PACK Dam. The peak discharge of 2500 m^3/sec at the upstream dam would be reduced to a peak inflow into HIERSMANN Dam of 2380 m^3/sec. Breaching of that structure would raise the peak back to 2500 m^3/sec. During passage of the flood wave down the steep and rough valley of the TEIGITSCH and KAINBACH, the peak would be reduced considerably, resulting in an increase of 850 m^3/sec over base flow in the MUR River at WILDON (MUR River Km 155), located near the confluence of the KAINBACH and MUR Rivers, approximately 68 km downstream from PACK Dam or 56 km below HIERSMANN Dam. The resulting increase above base flow conditions would be 475 m^3/sec at the confluence of the MUR and DRAU Rivers and 205 m^3/sec at D. MIHOLJAC (DRAU River Km -190). The wave crest would be 3.5 m above base flow at WILDON and only 0.7 m at D. MIHOLJAC, as shown in Table 6 and on Plate 12.

(3) Artificial Flood No. 6 represents the effects of increasing the size of breach opening. It differs from Flood No. 5 in that the bottom widths of the breach openings were doubled, being 20 m

wide at the bottom of the breach in this case. The peak discharge of 4050 m^3/sec at PACK Dam would result in a peak inflow of 3600 m^3/sec into HIERSMANN Reservoir. Breaching of that dam, 0.3 hours after the initial breaching of PACK Dam would raise the peak discharge back to 4050 m^3/sec. The increase in discharge over base flow would be 930 m^3/sec at WILDON, 510 m^3/sec at the confluence of the MUR and DRAU Rivers, and 215 m^3/sec at D. MIHOLJAC, only slightly greater than for Flood No. 5. The wave crest would raise the stage at WILDON 3.8 m compared to 3.5 m for Flood No. 5. The increase in stage of 0.7 m at D. MIHOLJAC would be identical for both floods. The effects are considerably less than for the DRAU River flow variations (Floods Nos. 1 to 4), as may be seen in Table 6 and on Plate 12. The shape and duration of the flood wave at representative locations may be seen by examination of the stage hydrographs of Flood No. 6, plotted on Plate 13.

e. Comparison of Effects of Major Flood Waves. Breaching of the PACK and HIERSMANN Dams would produce large flood waves in the TEIGITSCH and KAINBACH valleys, bankfull flow on the MUR River, but only minor increase in discharge, depth and velocity on the DRAU River downstream from those structures. The magnitude would be considerably less on the DRAU River than for the flow variations induced by discharge from the DRAU River dams discussed in paragraph 4-03. Increasing the size of breach would produce but slight increase in effects especially along the MUR and DRAU Rivers, as evidenced by the comparative results of Floods Nos. 5 and 6. Reference is made to the summary of effects, Table 6, to the discharge, depth, and velocity profiles on Plate 12, and to the stage hydrographs of Plate 13 for comparative results of the various artificial floods. Representative effects of major artificial flood waves at selected key locations are presented below to facilitate comparison of results:

Flood No.	Depth m	Width Flooded km	Overflow height m	Mean Surface Velocity m/sec	Duration above Base Flow hr
At WILDON (MUR R. Km 155)					
5	5.5	0.2	0.8	2.9	6
6	5.8	0.2	1.1	3.0	6
At D. MIHOLJAC (DRAU R. Km -190)					
5	2.6	0.5	Within banks	1.1	12
6	2.6	0.5	Within banks	1.1	12

4-05 ARTIFICIAL FLOODING POTENTIALITIES OF CANALS AND LAKES.

a. Canals. Since there are no navigation canals in the area, artificial flooding can not be produced from that source. Blocking of drainage canals and channels, coupled with breaching of dikes and destruction of drainage pumps could create "Drainage Obstacles" as described in paragraph 4-02.

b. Lakes. The possibility of utilizing the large volume of water stored in the many lakes of the region (described in paragraph 2-11 and in Exhibit A) for purposes of artificial flooding was not investigated. The lack of available data as to elevations, locations and nature of the lake outlets preclude any quantitative estimate of their utility for artificial flooding. However, over 50 million m^3 of water would be made available by raising the lake surface 1 m by means of regulated weirs. Most of the lakes lie in the upper headwaters of the region, and the lake bottoms lie much lower than the outlets. Consequently, unless the outlet elevations could be lowered or the lake level raised, only a limited volume of water would be available for release and the effect in the lower reaches of the river basin would not be appreciable. The lakes and glaciers probably would assist in maintaining a more uniform natural stream flow by temporarily retaining the precipitation of intense storms.

4-06 SUMMARY.

a. The hydraulic features associated with artificial flooding potentialities of the DRAU and MUR Rivers described in preceding paragraphs 4-01 to 4-05 are herein summarized. Reference should be made to Section V of this report for discussion of associated influence upon military operations.

b. Temporary damming of the streams at suitable bridge openings or other constrictions could create still-water barriers at widely separated locations along the lower reaches of the DRAU and MUR Rivers. Resulting inundated areas would range from 2 to 7 km in length and 0.5 to 7 km in width and up to 1 m in depth. Formation of a continuous still-water barrier along those streams would not be feasible. Blocking of normal drainage outlets in the marshy areas along the lower reaches of DRAU and MUR Rivers and in the KLAGENFURT Basin could increase the obstacle afforded by natural swamps and marshes. The steep stream gradients, high banks, and narrow valleys of the upper reaches offer few opportunities for creation of significant still-water barriers. Inundation possibilities are summarized in Table 5 and described in detail in paragraph 4-02. Locations and extent of still-water barriers are indicated on Plates 10a and 10b.

c. Coordinated opening of the large weir gates of the SCHWABECK, LAVAMUEND, DRAVOGRAD, VUZENICA, FALA and MARIBOR (Serial Nos. 1-6) power dams, located on the DRAU River near the present Austrian-Yugoslavian border, would produce large artificial flow variations in the DRAU River downstream from those structures. Cyclic variations could be repeated at 2 to 10 day intervals, depending upon replenishment of reservoir storage.

Significant effects could be attained even with partial gate openings. Reference is made to the summary of effects for Artificial Floods No. 1 and 2 in Table 6, to the discharge, depth and velocity profiles of Plate 12; to the representative stage hydrographs of Plate 13; and to the discussion contained in paragraph 4-03. A tabulation of pertinent effects of coordinated opening of the gates of these dams follows:

Item	Unit	DRAU RIVER ORMOZ (Km. 12)	D. MIHOLJAC (Km. -190)
Amplitude of rise	m	2.7-5.3	2.0-2.9
Duration above base flow	hr	13-32	18-38
Rate of rise	m/hr	0.7-1.3	0.2-0.3
Time of crest	hr	10-14	42-45
Overbank depth	m	1.9-4.5	Bankfull
Width flooded	km	2-5	0.5
Max. mean surface vel.	m/sec	3.1-3.3	1.1

d. Sudden opening of the large weir gates of SCHWABECK power dam (Serial No. 1), in the event that this dam is full and the other six downstream dams are empty or destroyed, could produce significant flow variations in the DRAU River upstream of the MUR River confluence. Flow would remain mostly within banks in the lower reaches below the MUR River, except in the flat delta near the confluence of the DANUBE River, where banks are low. Similar results could be attained by releases from MARIBOR Dam (Serial No. 6), the farthest downstream of the group of dams. Cyclic variations could be repeated at 1/2 to 3 day intervals if the reservoir storage is replenished by natural stream flow. MARIBOR releases could be repeated four times at approximately 6 hour intervals by successive transfer of water stored in the upstream pools to MARIBOR pool for sudden release from that dam. Cyclic variations by successive releases from each of the six dams, starting with the farthest downstream, could also be produced. The effects of releases from the smaller reservoirs would not be as great as of releases from SCHWABECK or MARIBOR. The effects produced by partial gate openings tend to approach those produced by full gate openings in the lower reaches, as indicated by comparison of the results of Artificial Floods Nos. 3 and 4. The duration and peak values of the effects produced by these flow variations from a single reservoir are considerably lower than produced by coordinated releases from all six reservoirs of the DRAU River group. The results of the flow variations studied, are discussed in paragraph 4-03 and summarized in Table 6. The peak discharge, depth and velocity profiles are plotted on Plate 12 and representative stage hydrographs are presented on Plate 13. A tabulation of representative effects of partial and full opening of gates of SCHWABECK Dam, as indicated by Artificial Floods Nos. 3 and 4 follows:

4-06d

Item	Unit	DRAU RIVER ORMOZ (Km. 12)	D. MIHOLJAC (Km -190)
Amplitude of rise	m	1.5-2.1	1.0
Duration above base flow	hr	8-20	13-22
Rate of rise	m/hr	0.3-0.5	0.1
Time of crest	hr	14-17	46-50
Overbank depth	m	0.7-1.3	Within banks
Width flooded	km	2-4	0.5
Max. mean surface vel.	m/sec	2.8-3.0	1.1

e. Synchronized breaching of the PACK and the HIERSMANN Dams (Serial Nos. 7 and 8) of the TEIGITSCH River power development would produce large artificial flood waves on the TEIGITSCH and KAINBACH valleys, moderate waves in the lower MUR River valley, but only small waves in the lower DRAU River downstream of the structures. The effects in the DRAU River would be much less than from the flow variations produced by releases from the DRAU River Dams described in the preceding paragraphs 4-06c and 4-06d. Flood waves in the MUR River produced by these dam breachings might be considerably moderated by coordinated operation of the existing MUR River power dams to reduce the magnitude of the peak. Detailed discussion of the potential effects attainable by breaching of the TEIGITSCH dams appears in paragraph 4-04; effects of artificial floods studied are summarized in Table 6. Comparative discharge, depth and velocity profiles are plotted on Plate 12; representative stage hydrographs are shown on Plate 13. Critical representative effects of Artificial Floods Nos. 5 and 6 at key locations on the MUR and DRAU Rivers, as produced by synchronized breaching of PACK and HIERSMANN Dams, are presented in the following tabulation:

Item	Unit	WILDON (MUR R. Km 155)	D. MIHOLJAC (DRAU R. Km -190)
Amplitude of rise	m	3.5-3.8	0.7
Duration above base flow	hr	6	12
Rate of rise	m/hr	1.7-1.9	0.1
Time of crest	hr	9	48
Overbank depth	m	0.8-1.1	Within banks
Width flooded	km	0.2	0.5
Max. mean surface vel.	m/sec	2.9-3.0	1.1

f. The breaching of PACK and HIERSMANN Dams* with the sudden gate opening of the SCHWABECK-MARIBOR DRAU River Dams would slightly increase the magnitude of the DRAU River flow variations discussed in preceding paragraphs 4-06c and 4-06d. Due to the flat shape of the hydrographs in the lower reaches of the DRAU River, the coordination of peaks that would produce maximum effectiveness could be accomplished by delaying the opening of the DRAU River dams from zero to six hours after breaching PACK and HEIRSMANN Dams. For example, coordination of the largest of the two breaches considered (Flood No. 6) at the PACK and

*/synchronized

4-06f

HIERSMANN Dams with each of the flow variations considered produced by releases from the DRAU River Dams (Floods 1 to 4) would increase the stages resulting from these flow variations as indicated in the following tabulation:

Location	Stage Increase (m) due to Flood No. 6 plus Floods Nos.: 1	2	3	4
BARCS	0	0.2	0.5	0.6
D. MIHOLJAC	0.05	0.05	0.2	0.2

The increase in velocity and width of flooding due to such combinations would not be large.

g. Sudden opening of the large gates of the numerous small power dams, weirs, and canals located along the MUR River, would produce moderate flow variations for short distances downstream from the opened structures. Reference is made to the general map, Plate 1; the stream profile, Plate 4d; the table of power projects, Table 4; and to the descriptions of the MUR River, Exhibit B. Insufficient data were available to permit evaluation of the effects. However, due to the small volume of storage included in the individual reservoirs, it is believed that measurable flow variations would only persist for a short distance downstream from the point of release. It might be possible to increase the duration, amplitude and effective travel distance by timing releases from successive structures to coincide with the arrival of the wave as it traveled downstream. Analysis of this possibility would require considerably more time and basic data than were available for this report.

h. The power outlets of the dams in the DRAU River basin are of too small discharge capacity as compared to stream channel capacity to have an appreciable effect upon artificial flooding potentialities, except insofar as they could be utilized to increase the natural stream flow to provide water for still-water barriers or for downstream reservoirs. Since most of the power projects are "run-of-the-river" plants, they include large gated openings to pass the high river flows. Operation of these gates (as illustrated in paragraph 4-06c and 4-06d above), would be more productive for artificial flooding than demolition or operation of the small power outlets.

i. Demolition or failure of the temporary dams used for still-water barriers discussed in paragraphs 4-02 and 4-06b would produce flood waves of short duration and magnitude. Significant effects would not be produced except in the reaches located within several kilometers below the destroyed barrier. Failure of such temporary dams might be caused by flow overtopping the structure. Therefore, adequate relief spillways or outlets should be provided.

4-06

j. The effects of artificial flood waves or flow variations depend largely upon the base flow (i.e., the flow in the stream before arrival of the flood). The studies presented in this report were based upon an assumed base flow approximating mean water conditions. The following tabulation illustrates the comparative effects produced by Flood No. 1 at ORMOZ (Km 12) with base flows of 400 m^3/sec (approximating mean water flow) as used in Table 6 and 2000 m^3/sec (approximating mean high water conditions).

	Item	Unit	ORMOZ		Source
(1)	Base flow	m^3/sec	400	2000	Assumed
(2)	Discharge increase	m^3/sec	4960	4960	Table 6
(3)	Crest discharge	m^3/sec	5360	6960	(2) plus (3)
(4)	Initial gage height	cm	55	300	Plate 8c for (1)
(5)	Crest gage height	cm	580	690	Plate 8c for (2)
(6)	Stage increase	m	5.25	3.90	(4) minus (5)
(7)	Initial Mean Surface Velocity	m/sec	2.3	3.1	Plate 8c for (4)
(8)	Crest Mean Surface Velocity	m/sec	3.3	3.4	Plate 8c for (5)
(9)	Velocity increase	m/sec	1.0	0.3	(7) minus (8)

SECTION V
EFFECT ON MILITARY OPERATIONS

5-01 GENERAL.

The purpose of this section is to assist military planning personnel in estimating the relative value and effect of artificial floods upon associated military factors such as bridging, ferrying, and trafficability. The effects of artificial floods upon military operations may vary greatly, depending on the hydrologic and weather conditions, the tactical and logistical situation, and the type of equipment involved. Reference is made to Section IV for discussion of the hydraulic features associated with artificial flooding.

5-02 CHARACTERISTICS OF MILITARY BRIDGING.

a. The loading capacities of standard U. S. Army floating bridging under conditions classified as "Safe, Caution, and Risk Crossings," for various current velocities are tabulated in Table 7. Included are the current velocities that presumably would destroy the bridge in place with no load, the values ranging from 9 to 16 feet per second (i.e., about 2.7 to 4.9 m/sec). Table 7 is primarily based on data contained in References 61 and 62.

b. It should be noted that the velocities shown in Table 7 represent general averages. The ability of floating bridges to withstand current velocities depends upon numerous variable factors, such as: special provisions for securing the bridge, the rate of change in river stage, direction and variability of current, debris carried by the stream and other considerations. Standard bridging has withstood conditions more severe than indicated in Table 7 and has failed under apparently less critical velocities.

5-03 EFFECTS OF ARTIFICIAL FLOODING DURING ACTUAL CROSSING OPERATIONS.

No information is available regarding details of actual military river crossing operations along the streams in the DRAU River Basin, nor of the observed influence of artificial flooding upon such operations.

5-04 EFFECT OF STILL-WATER BARRIERS AND DRAINAGE OBSTACLES.

a. Reference is made to paragraphs 4-02 and 4-06 for discussion of the hydraulic features associated with formation and augmentation of water obstacles by means of temporary damming operations or by disruption of normal drainage.

b. Bridging and ferrying operations within the backwater reaches upstream from the temporary dams would be hindered by reason of the resulting greater width and depth of crossing, indicated in

Table 5 and on Plates 10a and 10b. Approach trafficability would be reduced by the shallow overbank flooding and the increased stream depths would hinder fording at shallow spots in the affected reaches of the river. Since the resulting increased water obstacles would not be continuous along the streams (as illustrated on Plates 10a and 10b), still-water barriers must be combined with other natural obstacles and with tactical operations in order to channelize military action.

c. Inundation of low-lying land in the river meander zone along the lower reaches of the DRAU River, such as that shown on Plate 10b as created by still-water barriers and drainage obstacles would reduce overland trafficability for extended periods. The multiple shifting channels and river meanders in these reaches do present considerable natural obstacles to river crossing operations. Much of the area along the lower reaches has inadequate drainage and is naturally inundated or marshy for most of the year as a result of natural floods. Artificial flooding would prolong and intensify the natural marshy conditions.

d. Some obstacle to river crossing operations could be created along the lower MUR River by erection of still-water barriers, notably in the flat delta at the confluence of the LEDAVA and DOBEL Rivers as discussed in paragraph 4-02.

e. Temporary damming of streams and blocking of natural drainage in the KLAGENFURT Basin near the DRAU River would inundate this marshy area. Combined with the WOERTHER SEE, this would present a considerable obstacle to overland traffic and bridging operations in the vicinity of the important communication center of KLAGENFURT.

f. Erection of temporary dams or raising the crests of existing dams in the upper reaches of the DRAU or MUR Rivers would not appreciably affect military operations, as the water obstacle would not extend much beyond the river banks. The increased depth, however, could hinder fordings at shallow spots upstream from the structures.

g. Continuous military support of the temporary dam installations would be necessary to prevent their destruction by enemy air or ground action. Destruction or failure of a temporary dam would release a flood wave of short duration that would temporarily hinder crossing operations below the structure and which might cause progressive failure of other downstream structures.

h. Breaching of levees would be necessary in some cases; while, in others, blocking of culverts and drainage outlets would be required in addition to temporary damming operations in order to create effective still-water barriers and drainage obstacles.

5-05 EFFECT OF FLOW VARIATIONS.

a. Reference is made to paragraphs 4-03 and 4-06 for discussion of the possible detrimental flow variations that could be created on the DRAU River by means of regulated discharge from the large gated openings of the DRAU River power dams at SCHWABECK, LAVAMUEND, DRAVOGRAD, VUZENICA, FALA and MARIBOR (Serial Nos. 1-6 on Plates 1, 9a and 9b. Resulting flow conditions are summarized in Table 6 and presented graphically on Plates 12, 13a and 13b.

b. Sudden opening of the large gates at these dams would produce appreciable flow variations along the DRAU River that would endanger floating bridging, especially in the reach between the dams and the confluence of the MUR River. Under normal conditions of reservoir storage, stream flow and outlet facilities, it would also be possible to repeat flow variations to create cyclic effects. Downstream of the MUR River confluence, the resulting velocities would be too low to seriously hinder floating bridging operations. However, the increase in effective stream width to cover the meander belt could hinder crossing operations in that reach.

c. No appreciable effect on bridging or crossing operations could be expected by release of water from the small power outlets of those dams.

d. Release of water from the large gated openings of the numerous MUR River power dams (Serial Nos. 9-14) would produce flow variations that would interfere with bridging and crossing operations along the MUR River for short distances downstream from the individual structures. The possibility of coordinated releases from a number of those dams was not investigated, but would intensify the effects if properly coordinated. Due to the multiplicity of dams and of other factors, such coordination would involve complex timing in opening or demolition of the various structures.

e. Similarly, sudden release of flow from the large gates of the many other existing hydroelectric dams located in the headwater tributaries of the DRAU River (see Serial Nos. 15-29 on Plate 1 or in Table 4) would produce flow variations. However, appreciable effect on military operations would probably not be significant except for short distances below the structures.

f. Opening the gates of the DRAU and MUR River hydroelectric dams would probably not seriously damage existing permanent bridges, as the dam outlets (and also the bridges) are designed to handle the maximum expected natural floods.

g. Deliberate destruction of the structures or gates of the DRAU and MUR River dams and other power dams in the basin would prevent their use by the enemy in producing detrimental flow variations during a later critical period and would seriously disrupt the electrical power facilities of the region.

h. Water stored in the reservoirs of the DRAU and MUR River dams as well as in the reservoirs of other hydroelectric dams in the area could be released to provide a supplementary supply of water for still-water barriers previously discussed in paragraphs 4-02 and 5-04.

i. In order to utilize the gates of the dams in the DRAU River basin to produce flow variations, it would be necessary to provide for defense of the sites against enemy air or ground attacks. Breaching of the structures or damage to the operating mechanism by enemy action would prevent useful operation of the gates, especially where cyclic releases are concerned.

5-06. EFFECT OF MAJOR FLOOD WAVES.

a. Reference is made to paragraphs 4-04 and 4-06 for discussion of the hydraulic features associated with creation of major flood waves by breaching the PACK and HIERSMANN Dams (Serial Nos. 7 and 8 on Plates 1 and 9d) of the TEIGITSCH power development in the MUR River basin.

b. Flood waves caused by breaching of those dams would probably destroy or seriously damage bridges along the TEIGITSCH and KAINBACH Rivers downstream of those structures. The resulting rapid increase of stage in the MUR River might hinder floating bridge operations on that river below the confluence of the KAINBACH River but would probably not endanger fixed bridges. Very little effect on stream crossing operations could be expected along the lower DRAU River.

c. The flood waves created by breaching SCHWABECK-MARIBOR group of dams (Serial Nos. 1-6 on Plates 1, 9a and 9b) on the DRAU River or the MUR River dams (Serial Nos. 9-14 on Plate 1) would endanger floating bridging along the DRAU and MUR Rivers downstream from those structures, but probably would not damage existing permanent bridges. Since the large gates in those dams cover practically the entire cross-section of the dams, the effects would approximate those created by sudden gate openings discussed in preceding paragraph 5-05. Breaching would eliminate the possibility of cyclic releases by gate operations.

d. Breaching of the higher dams located on the headwater tributaries such as the two dams of the MARGARITZE Reservoir (Serial No. 21) in the MOELL River basin would create major flood waves that could destroy or endanger low bridges for short distances downstream from the breached structure. However, very slight interference with crossing operations might be expected along the main streams of the region. The released water could supplement other sources of supply

5-06

for the still-water barriers discussed in paragraphs 4-02 and 5-04 and also help to refill the reservoirs used to create flow variations discussed in paragraphs 4-03 and 5-05.

e. The electrical power supply of a large part of South Austria and North Yugoslavia would be seriously disrupted by breaching the numerous hydroelectric power dams in the DRAU and MUR River basins.

f. Breaching of levees and destruction of drainage facilities might be necessary in some cases in order to fully exploit the maximum possible effectiveness of artificial flood waves.

g. Military support of permanent or temporary dam installations would be necessary to prevent their destruction by enemy air or ground action. Such destruction would prematurely release flood waves that could hinder action by our forces below the breached structures. Deliberate demolition of dams or barriers would prevent their use by the enemy in producing detrimental major flood waves or flow variations during a later critical period.

5-07 EFFECTS RELATED TO OTHER BASINS.

a. Artificial flooding along the DRAU and MUR Rivers could be coordinated with similar operations on other nearby river basins to create simultaneous or progressive water obstacles affecting military actions. Specific reference is made to a similar study on the SAVA River basin of Yugoslavia, recently completed by this office and listed as Reference 63 in the Bibliography of this report. Additional studies are currently being made by this office on the rivers of the VENETIAN-FRIULI PLAINS of NORTHEAST ITALY and also on the streams of the AUSTRIAN ALPS located just north of the DRAU River basin.

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TABLES

TABLE I
EQUIVALENT ENGLISH-METRIC TERMS

To reduce A to B, multiply A by F. To reduce B to A, multiply B by G.

Unit A	Factor F	Factor G	Unit B
	LENGTH		
Miles	1.60935	.62137	Kilometers
Meters	3.2808	.30480	Feet
Meters	39.370	.025400	Inches
	AREA		
Square Miles	2.590	.3861	Square Kilometers
Square Miles	259.000	.0038610	Hectares
Hectares	2.47104	.40469	Acres
Acres	4046.9	.00024710	Square Meters
	VOLUME		
Cubic Meters	35.3145	.028317	Cubic Feet
Cubic Feet	28.317	.035314	Liters
Acre-feet	43560.	.000022957	Cubic Feet
Acre-feet	1233.5	.00081071	Cubic Meters
	DISCHARGE		
Cubic feet per second	1.9835	.50417	Acre-feet per 24 hours
Cubic meters per second	35.3145	.028317	Cubic-feet per second
	VELOCITY		
Miles per hour	1.60935	.62137	Kilometers per hour
Miles per hour	1.4667	.68182	Feet per second
Meters per second	3.2808	.30480	Feet per second
Meters per second	2.2369	.44704	Miles per hour
Meters per second	3.600	.2778	Kilometers per hour
Feet per second	1.097	.9113	Kilometers per hour
	WEIGHT		
Tons (metric)	1.102	.9072	Tons (short)
Tons (long)	1.016	.9842	Tons (metric)
Tons (metric)	2205.	.0004536	Pounds (avoirdupois)
Tons (metric)	1000.	.001	Kilograms
	POWER		
Horsepower (std. U.S.)	550.	.0018182	Foot-pounds per second
Horsepower (metric)	75.	.01333	Kilogram-meters per second
Horsepower (std. U.S.)	1.014	.9863	Horsepower (metric)
Kilowatts	1.3405	.7457	Horsepower (std. U.S.)
Kilowatts	1.360	.7355	Horsepower (metric)

TABLE 2

HYDROLOGIC TERMS AND ABBREVIATIONS

(In conformance with German practice)

Non-Tidal Stage	High-Tide Stage	Low-Tide Stage	Rate of Discharge (m^3/sec)	Discharge per Unit area (1/sec-km^2)	Definition
HHW	HHThw	HHTnw	HHQ	HHq	Highest value ever known or observed
HW	HThw	HTnw	HQ	Hq	Highest value observed during a stated period of time
MHW	MHThw	MHTnw	MHQ	MHq	The mean high value during a stated period, derived by averaging the highest values of each unit time element (i.e. MHW 1926/35 is average of the 10 yearly peak stages)
MW	MThw	MTnw	MQ	Mq	The mean (arithmetical average) of all observations during a stated time period
MNW	MNThw	MNTnw	MNQ	MNq	The mean low value during a stated period, derived by averaging the lowest values of each unit time element (MNW 1926/35 is the average of the 10 yearly lowest stages)
NW	NThw	NTnw	NQ	Nq	Lowest value observed during a stated period of time
NNW	NNThw	NNTnw	NNQ	NNq	Lowest value ever known or observed

Table 2

RESTRICTED
SECURITY INFORMATION

TABLE 3

SUMMARY OF GAGE DATA - DRAU (DRAVA) RIVER(2)

Gaging Station Number	Name*	River*	U.T.M. Grid Coordinates	River KM***	Drainage Area Km^2	Approximate Top of Bank m.ü.A. (Meters above Adriatic Sea)	Approximate Stream Bed m.ü.A. (Meters above Adriatic Sea)	Gage Zero Year	Gage Zero m.ü.A.	Minimum Date	Minimum NNW cm	Mean Period	Mean MW cm	Mean MQ m^3/sec	Maximum Date	Maximum HHW cm	Maximum HHQ m^3/sec
AUSTRIA																	
1	SILLIAN	DRAU	UM030804	400.13	183.3	1080	-	1940 1933	1066.76 1069.76	31/12/99 31/12/99	60 -40	-	-	-	12/10/89 12/10/89	350 250	-
2	TASSENBACH	DRAU	UM065803	396.57	378.6	1063	1055.7	1940	1056.90	14/2/28	10	-	-	-	28/9/42	196	-
3	THAL	DRAU	UM215838	379.40	597.4 597.7	820	809.8	1939 1933	810.53 813.53	9/3/28 9/3/28	-370 -70	-	-	-	28/9/42 5/6/24	192 -120	-
4	BRÜHL	ISEL	UM135058	26.85(3)	518.4	925	921.0	1940 1933	921.00 923.80	17/2/33 25/3/32	78 -20	-	-	-	7/7/46 20/7/31	513 220	-
5	ST. JOHANN IM WALDE	ISEL	UM196974	15.75(3)	1077.8	751	744.8	1939	745.76	2/1/47 3/3/09	48 -40	-	-	-	14/9/03 14/9/03	380 280	-
6	PATRIASDORF	ISEL	UM285894	2.27(3)	1192.1	675	-	1932	673.55	28/2/30	18	-	-	-	20/7/31	320	-
7	LIENZ	ISEL	UM295892	1.21(3)	1198.7	673(1)	668.6	1936	669.93	21/1/43	85	-	-	-	9/8/45	380	-
8	LIENZ	ISEL	UM302889	.60	1197.5	675(1)	-	1931	669.29	29/3/18	-25	-	-	-	20/10/89	270	-
9	LIENZ	DRAU	UM298883	369.27	671.9	672	671.2	1933	671.20	28/3/42	1	-	-	-	20/10/86	290	-
	MOUTH OF ISEL R.		UM308885	368.4	-	670	-	-	-	-	-	-	-	-	-	-	-
**10	LAVANT	DRAU	UM358861 UM358861 UM360858	362.47 362.47 362.20	1989.8 1989.8 1984.4	649(1) -	645.0 -	1940 1933 1930	645.49 646.49 645.95	27/2/94 19/3/31 27/2/94	90 38 -14	- - 1924-30	- - 102.3	- - 42	14/9/03 20/7/31 14/9/03	527 253 410	- 800(7)(e)

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NOTES:
*Austrian stations are identified by Austrian names
Yugoslavian stations are identified by Yugoslavian names with Austrian names in parenthesis
(Austrian name of the river is DRAU; Yugoslavian name is DRAVA)
**Discharge rating curve Plate #7
***ZERO kilometer at old AUSTRIA-HUNGARY Border which is 262 km above mouth of DRAVA River

(1) Approx. top of dikes
(2) See paragraph 3-03 for source of data
(3) Kilometers above mouth of river
(e) Estimated

RESTRICTED
SECURITY INFORMATION

TABLE 3

RESTRICTED

SECURITY INFORMATION

SUMMARY OF GAGE DATA - DRAU (DRAVA) RIVER [2]

Gaging Station Number	Name*	River*	U.T.M. Grid Coordinates	River Km***	Drainage Area Km²	Approximate Top of Bank m.ü.A. (Meters above Adriatic Sea)	Approximate Stream Bed m.ü.A. (Meters above Adriatic Sea)	Gage Zero Year	Gage Zero m.ü.A.	Minimum Date	Minimum NNW cm	Mean Period	Mean MW cm	Mean MQ m³/sec	Maximum Date	Maximum HHW cm	Maximum HHQ m³/sec
AUSTRIA																	
11	NIKOLSDORF	DRAU	UM3938[illegible]	357.67	2039.1	636	634.9	1933	634.92	22/2/89	-50	-	-	-	14/9/03	240	-
**12	OBERDRAUBURG	DRAU	452793	349.94	2112.0	620[1] 618	616.5 -	1939 1933	616.62 617.62	26/2/94 27/1/94	35 -65	1924-33	47	60	12/10/89 12/10/89	427 327	720
13	DELLACH i DRAUTAL	DRAU	533775	341.06	2196.4	605[1]	599.9	1933	599.95	13/2/16	-6	-	-	-	17/9/82	303	-
14	ALTENMARKT	DRAU	572783	336.93	2272.1	595[1]	592.9	1933	593.13	31/1/16	-20	-	-	-	14/9/03	310	-
15	BRUGGEN	DRAU	617778	331.75	2350.0	588[1]	584.0	1933	584.53	21/2/03	-58	1924-33	87	-	2/11/51	329	-
16	STEINFELD	DRAU	673793	325.35	2411.7	580	-	1933	576.58	31/12/93	-20	-	-	-	2/11/51	360	-
17	KLEBLACH	DRAU	736815	318.10	2474.8	-	-	1933	565.82	18/1/22	-75	-	-	-	18/11/82	270	-
18	SACHSENBURG	DRAU	743073	311.70	2566.0	-	-	1933 1939	556.05 555.05	15/2/22 15/2/22	-57 43	1924-33	119.1	-	18/11/82 18/9/82	340 440	-
19	WINKLERN	MÖLL	369939	51.96[3]	412.1	-	-	1939 1933 1926	676.23 677.23 676.94	25/3/33 1/3/31 24/1/22	60 -37 -35	1931-40	104	-	9/8/45 5/10/35 24/5/08	265 190 136	-
20	STALL	MÖLL	512949	34.77[3]	543.5	-	-	1948	761.733	-	-	-	-	-	-	-	-
21	OBERVELLACH	MÖLL	631992	14.10[3]	663.0	-	-	1933	666.78	25/1/96	-65	-	-	-	14/9/03	196	-
22	KOLBNITZ	MÖLL	701934 711928	9.32[3] 8.24[3]	1044.2 1046.7	-	-	1939 1933	606.46 605.46	20/3/09 20/3/09	-70 30	- 1931-40	- 79	- -	14/9/03 14/9/03	180 285	- -
23	MÖLLBRÜCKE	MÖLL	75[illegible]	1.48[3]	108[illegible]	-	-	1933 1940	557.03 555.03	15/3/31 4/3/47	-81 88	1924-33	-31.2	-	14/9/03 14/9/03	270 470	- -
MOUTH OF MÖLL R.			766874	308.20	-	-	-		-	-	-	-	-	-	-	-	-
24	GSCHIESS	DRAU	796868	305.10	357[illegible].5	-	543.1	1933	543.70	15/2/31	-60	1924-33	24.6	-	19/6/18	240	-
25	SCHWAIG	DRAU	847825	297.38	3737.8	-	- 531.2	1933 1940	532.23 531.23	5/3/88 20/3/39	3 103	- -	- -	- -	18/11/82 18/9/82	460 560	-
26	GMÜND	LIESER	895963 906967 917976	19.06[3] 18.07[3] 17.20[3]	358.0 350.1 351.8	-	-	1924 1932 1939	768.80 759.35 748.43	24/3/44 10/3/30 JAN 1922	63 -12 0	-	-	-	7/7/46 20/7/31 27/5/14	276 160 120	-
27	RADL	LIESER	882954	14.75[3]	632.3	-	-	1930	703.02	8/1/22	-45	-	-	-	5/10/07	240	-
28	MILLSTATT	MILLSTATER SEE	940830	10.00[3]	286.3	-	-	1933 1940	587.97 586.97	6/1/22 8/1/22	3 103	-	-	-	21/5/17 21/5/17	133 233	- -

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NOTES: See page 1, Table 3

RESTRICTED

SECURITY INFORMATION

RESTRICTED

TABLE 3 SECURITY INFORMATION

SUMMARY OF GAGE DATA - DRAU (DRAVA) RIVER(2)

Gaging Station Number	Name*	River*	U.T.M. Grid Coordinates	River Km***	Drainage Area Km^2	Approximate Top of Bank m.ü.A. (Meters above Adriatic Sea)	Approximate Stream Bed m.ü.A. (Meters above Adriatic Sea)	Gage Zero Year	Gage Zero m.ü.A.	Minimum Date	Minimum NNW cm	Mean Period	Mean MW cm	Mean MQ m^3/sec	Maximum Date	Maximum HHW cm	Maximum HHQ m^3/sec
AUSTRIA																	
29	SEEBRÜCKE	MILLSTÄTER SEEBACH	UM364856	1.09(3)	286.3 286.0	-	-	1933 1940	586.97 587.97	3/3/22 3/3/27	99 -1	1924-33	26.2	-	21/5/17 21/5/17	230 130	-
30	SEEBACH	LIESER	854862	4.57(3)	1034.3	-	-	1941	578.20	30/1/47	65	-	-	-	7/7/46	440	-
31	SPITTAL	LIESER	852858 853853	4.10(3) 3.28(3)	1023 1024	- -	-	1929 1930	572.84 558.47	14/1/22 1923	-90 <-85	-	-	-	24/5/08 25/9/24	205 110	-
32	SPITTAL A.D. DRAU	LIESER	854848 857841	2.62(3) 1.80	1024 1036.5	-	-	1933 1945	554.86 541.02	30/3/32 23/9/47	-65 82	-	-	-	20/7/31 7/7/46	120 328	-
MOUTH OF LIESER R.			856822	296.3	-	-	-	-	-	-	-	-	-	-	-	-	-
33	MAUTHBRUCKEN	DRAU	938777	286.05	4810.1	-	- 513.1	1933 1940	514.10 513.10	14/12/99 14/12/99	68 32	-	-	-	2/11/51 2/11/51	428 528	- -
**34	FEISTRITZ	DRAU	994728	278.32	4840.2	- 509	- 505.2	1933 1939	506.22 505.22	14/2/31 25/2/33	-40 54	1924-33	167.9 (Broken)	170	14/9/03 14/9/03	460 560	2300
35	TECHENDORF	WEISSENSEE	698752	10.00(3)	48.4 49.5 49.5	-	-	1940 1933 1928	926.23 927.23 926.96	16/9/11 16/9/11	83 -17	-	-	-	24/11/26 24/11/26	199 99	-
36	MÖSSLACHER	WEISSENSEE															
37	DUEL	WEISSENBACH	964727	2.31(3)	180.5 180.4	-	-	1929 1933	53[illegible].56 539.56	16/11/47 11/3/09	89 3	-	-	-	22/9/20 22/9/20	320 220	-
38	VILLACH	DRAU	VM132627	257.22	5266.4	490(1)	485.0	1940 1933	485.67 486.54	9/2/22 9/2/22	47 -53	1924-33	162	150	2/11/51 2/11/51	630 530	1900
39	ST. ANDRÄ	OSSIACHER SEE	155672	0.50(3)	165.4	-	-	1939 1933	500.57 501.57	30/4/44 9/2/22	79 -1	-	-	-	26/11/26 26/11/26	229 129	-
MOUTH OF OSSIACHER SEEBACH			143633	154.22	-	-	-	-	-	-	-	-	-	-	-	-	-
40	MAUTHERN	GAIL	UM470704	78.07(3)	346.8	-	-	1933 1939	697.85 692.85	26/1/20 22/2/35	-395 105	-	-	-	19/9/82 5/10/35	740 440	-
41	RATTENDORF	GAIL	662650	57.28(3)	594.4	-	-	1933 1940	596.10 595.10	25/1/97 12/3/40	-10 55	-	-	-	27/5/14 5/10/35	280 410	-

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Wash. Dist., Corps of Engineers, April 1953

NOTES: See page 1, Table 3

RESTRICTED
SECURITY INFORMATION

TABLE 3

RESTRICTED
SECURITY INFORMATION

SUMMARY OF GAGE DATA - DRAU (DRAVA) RIVER[2]

Gaging Station Number	Name*	River*	U.T.M. Grid Coordinates	River KM***	Drainage Area Km^2	Approximate Top of Bank m.ü.A. (Meters above Adriatic Sea)	Approximate Stream Bed m.ü.A. (Meters above Adriatic Sea)	Gage Zero Year	Gage Zero m.ü.A.	Minimum Date	Minimum NNW cm	Mean Period	Mean MW cm	Mean MQ m^3/sec	Maximum Date	Maximum HHW cm	Maximum HHQ m^3/sec
AUSTRIA																	
42	MODERNDORF	GAIL	UM749636	48.10[3]	754.9	-	-	1933	574.34	23/11/21	-20	-	-	-	14/9/03	360	-
43	NÖTSCH	GAIL	938601	26.36[3]	940.2	-	-	1933 1940	549.16 545.74	22/2/09 15/1/38	-150 124	-	-	-	14/9/03 14/9/03	315 615	-
44	FEDERAUN	GAIL	VM090582	8.74[3]	1304.8	-	-	1933 1940	500.02 502.02	23/2/40 19/2/22	91 -108	-	-	-	18/11/40 23/11/26	684 497	-
45	FAAK-INSEL	FAAKER-SEE	174557	0.60[3]	29.1	-	-	1921	559.64	1/2/45	16	-	-	-	14/10/33	98	-
46	TSCHINOWITSCH	GAIL	123606	2.95[3]	1408.7	-	-	1933 1948	489.17 488.17	16/2/29 12/2/25	-15 80	-	-	-	23/11/26 23/11/26	300 400	-
47	MARIA-GAIL	GAIL	137615	1.15[3]	1408.7	-	-	1927	485.82	21/11/21	10	-	-	-	14/9/03	355	-
MOUTH OF GAIL			148622	253.22	-	486	-	-	-	-	-	-	-	-	-	-	-
48	WERNBERG	DRAU	175631	249.56	7007.2	478	-	1933	479.68	15/12/99	-39	1924-33	72.7	-	14/9/03	572	-
**49	ROSEGG	DRAU	250607	238.87	7056.8	479	466.2	1939 1933	466.23 467.23	25/1/45 29/12/21	45 -57	1929-33	57.8	180	14/9/03 14/9/03	694 594	2000
50	HOLLENBURG	DRAU	433547	212.60	7273.1	-	-	1933 1939	425.89 423.75	5/3/32 24/1/42	-107 20	1924-33	-22	-	2/9/51 2/11/1851	386 586	-
51	ANNABRÜCKE	DRAU	612579	192.55	7577.6	-	392.2	1933	393.56	14/2/25	-140	-	-	-	13/9/89	500	-
52	MIKLAUZHOF	VELLACH	662529 669539 669539	11.85[3] 10.30[3] 10.30[3]	193.95 194.1 193.6	-	-	1933 1939 1927	481.33 459.12 460.12	26/9/21 26/9/21 26/9/21	-43 57 -43	-	-	-	30/10/26 30/10/26 30/10/26	317 417 300	-
53	SELESEN	GURK	596790	40.58[3]	1256.8	-	-	1940 1933	447.49 448.49	21/2/22 21/2/22	70 -30	-	-	-	9/7/46 22/9/20	300 190	-
54	REIDEG	GURK	627775	36.62[3]	1590.0	-	-	1933	478.18	11/2/22	27	-	-	-	9/9/16	200	-
55	ZOLLFELD	GLAN	531774	27.80[3]	432.3	-	-	1934	454.06	1946	30	-	-	-	14/10/33	232	-
56	ST. PETE. N. KLAG.	GLAN	478647	10.05[3]	548.6	-	-	1933	436.70	25/2/13	-35	-	-	-	15/12/16	105	-

Prepared by: Military Hydrology R&D Branch
Wash. Dist., Corps of Engineers, April 1953

NOTES: See page 1, Table 3

RESTRICTED
SECURITY INFORMATION

SUMMARY OF GAGE DATA - DRAU (DRAVA) RIVER(2)

Gaging Station Number	Name*	River	U.T.M. Grid Coordinates	River Km***	Drainage Area Km^2	Approximate Top of Bank M.ü.A. (Meters above Adriatic Sea)	Approximate Stream Bed M.ü.A. (Meters above Adriatic Sea)	Gage Zero Year	Gage Zero m.ü.A.	Minimum Date	Minimum NNW cm	Mean Period	Mean MW cm	Mean MQ m^3/sec	Maximum Date	Maximum HHW cm	Maximum HHQ m^3/sec
AUSTRIA																	
57	VELDEN	WORTHERSEE	VM274625	17.5(3)	1[illegible].3	-	-	-	439.06	-	-	-	-	-	-	-	-
58	FORSTSEE WERK	WORTHERSEE	338653	14.30(3)	160.1	-	-	1926	440.00	27/9/25	65	-	-	-	29/11/26	141	-
59	PÖRTSCHACH	WORTHERSEE	356643 365643	11.31(3) 9.25(3)	1[illegible].1 1[illegible].3	-	-	1933 1940	439.05 440.05	2/3/22 9/2/22	82 -18	-	-	-	19/12/16 19/12/16	210 110	-
60	KLAGENFURT	LEND-KANAL	435632	1.32(3)	158.3	-	-	1933 1939	439.98 439.01	1/10/57 10/10/57	-26 74	- 1924-33	- 29.7	-	12/12/72 12/12/72	110 210	-
61	KLAGENFURT OST	GLAN	470647	10.05(3)	557.5	-	-	1940	435.71	26/2/82	60	-	-	-	24/9/30	260	-
62	GURNITZ	GLAN	523617	4.40(3)	621.3	-	-	1933	412.94	10/2/25	55	1926-33	113.8	-	22/9/16	245	-
62	GURNISCH	GURK	596617 596617 603620	5.36(3) 5.36(3) 4.40(3)	2555.4 2555.0 2555.2	-	-	1939 1933 1925	395.94 396.94 395.47	3/1/09 3/1/09 3/1/09	96 -4 -4	1926-33	56.9	-	9/9/16 9/9/16 9/9/16	344 244 225	-
MOUTH OF GURK R.			636621	187.70	-	-	-	-	-	-	-	-	-	-	-	-	-
**64	NEUBRÜCKA	DRAU	655634	185.40	10391.4	392	383.0	1933 1939	384.74 383.74	20/1/01 20/1/01	-55 45	1924-33	50.1	260	13/10/89 13/10/89	336 436	2400
65	KLOPEIN	KLOPEINERSEE	685 15	1.77(3)	4.1	-	-	1933	446.58	31/12/21	105	-	-	-	8/9/24	166	-
66	VOLKERMARKT	DRAU	719662	176.05	10603.3	380	-	1933	376.36	1/12/63	-100	-	-	-	2/11/51	670	-
67	LIPPITZBACH	DRAU	832615	163.65	10871.5	362	356.3	1933 1937	359.78 359.86	13/1/96 13/1/96	-150 -150	-	-	-	2/11/51 2/11/51	852 852	- -
68	ST. GERTRAUD	LAVANT	-	39.70(3)	3[illegible].2	-	-	1946	511.61	22/5/46	55	-	-	-	26/12/46	176	-
69	WOLFSBERG	LAVANT	875400	31.55(3)	504.1	-	-	1933	449.94	7/3/99	-32	1924-33	18.6	-	18/10/07	205	-
70	METTERSDORF	LAVANT	877790	21.4(3)	766.2	-	-	1926	388.69	19/2/22	10	-	-	-	5/9/22	150	-
71	KROTTENDORF	LAVANT	935663	4.60(3)	955.8	-	-	1933	357.66	18/1/66	-12	-	-	-	15/7/26	360	-
72	LAVAMÜND	LAVANT	953665	1.46(3)	967.9	-	-	1939	344.97	1/6/43	79	-	-	-	25/5/38	270	-
73	LAVAMÜND	DRAU	956654	144.64	11040.9	(Gage discontinued)		1933	340.52	24/2/96	-9	1924-33	106.7	275	3/11/51	865	-

Prepared by: Military Hydrology Branch
Wash. Dist., Corps of Engineers, April 1953

NOTES: See page 1, Table 3

RESTRICTED
SECURITY INFORMATION

TABLE 3

SUMMARY OF GAGE DATA - DRAU (DRAVA) RIVER (2)

Gaging Station Number	Gaging Station Name*	River*	U.T.M. Grid Coordinates	River Km***	Drainage Area km²	Approximate Top of Bank m.ü.A. (meters above Adriatic Sea)	Approximate Stream Bed m.ü.A. (meters above Adriatic Sea)	Gage Zero Year	Gage Zero m.ü.A.	Minimum Date	Minimum NNW cm	Mean Period	Mean MW cm	Mean MQ m³/sec	Maximum Date	Maximum HHW cm	Maximum HHQ m³/sec
YUGOSLAVIA																	
74	PRAVOGRAD (UNTERDRAUBURG)	DRAVA	WM020596	136.44	12613.7	(Gage discontinued)		1912	328.98	16/2/01	-48	1901-10	91	-	3/11/51	910	-
75	VUZENICA (SAUDENHOFEN)	DRAVA	125610	124.00	12745.4	-	315.8	1912	315.94	26/12/99	-15	1901-10	98	-	15/[illegible]/03	505	-
76	(ST. OSWALD)	DRAVA	312585	100.76	13144.4	-	-		-	25/1/09	-60	-	-	-	19/10/07	660	-
77	(MARBURG)	DRAVA	495563	72.80	13433.8	(Gage discontinued)		1912	247.32	11/1/55	-37	1901-10	98	-	3/11/51	680	-
**78	MARIBOR (MARBURG)	DRAVA		-	13441.0	260	-	1944	246.92	10/1/22	-19	1923	108	340	15/9/03	450	2600
79	GORNJI DUPLEK (OBERTAUBLING)	DRAVA	549517	62.88	13514.7	-	-	1912	237.54	25/1/09	-15	-	-	-	15/9/03	365	-
**80	PTUJ (PETTAU)	DRAVA	668409	43.72	13637.7	220	215.1	1944	217.81	28/2/21	-60	1901-10	88	380	3/11/51	490	-
81	(ANKENSTEIN)	DRAVA	777365	28.42	14658.0	-	-	1912	213.49	26/1/09	-30	1901-10	72	-	16/9/03	340	-
82	BORL	DRAVA	-	-	14642.0	209	-	1944	203.49	1943	-20	1923	76	-	16/9/03	340	-
**83	ORMOZ (FRIEDAU)	DRAVA	906383	12.20	15351.1	190	187.0	1912	188.69	2/3/09	-75	1923	84	520	16/9/03	300	-
84	VARAŽDIN	DRAVA		-9	15616.0	168	165.9	1944	166.06	26/2/01	-16	1923	157	-	30/10/82	410	-
MOUTH OF MUR R.			-	-55	-	130	127.0(e)	-	-	-	-	-	-	-	-	-	-
85	BOTOVO-DRNJE	DRAVA	XM573147	-63	31,038	126	120.3	1944	122.25	6/1/40	-200	-	-	-	25/6/44	364	-
**86	BARČS	DRAVA	YL884913	-111	-	106	99.6	1944	100.82	-	-	-	120(e)	600(e)	-	-	[illegible]
87	TEREZINO POLJE	DRAVA	909911	-114	39,916	106	98.7	1944	100.61	25/1/33	-185	-	-	-	1876	452	-
**88	DONJI MIHOLJAC	DRAVA	BR825740	-190	37,142	93	88.1	1944	88.80	29/3/43	-72	1926	137	650	11/3/91	440	3000
89	OSJEK	DRAVA	-	-244	39,982	-	80.6	1944	81.48	25/1/33	-66	1926	205	-	16/7/26	482	-

Prepared by: Military Hydrology Branch
Wash. Dist., Corps of Engineers, April 1953

NOTES: See page 1, Table 3

RESTRICTED
SECURITY INFORMATION

RESTRICTED
TABLE 3 SECURITY INFORMATION

SUMMARY OF GAGE DATA – MUR (MURA) RIVER(2)

Gaging Station Number	Name*	River*	U.T.M. Grid Coordinates	River KM(3)	Drainage Area Km^2	Approximate Top of Bank m.ü.A. (Meters above Adriatic Sea)	Approximate Stream Bed m.ü.A. (Meters above Adriatic Sea)	Gage Zero Year	Gage Zero m.ü.A.	Date	Minimum NNW cm	Period	Mean MW cm	Mean MQ m^3/sec	Date	Maximum HHW cm	Maximum HHQ m^3/sec
AUSTRIA																	
90	ST. MICHAEL IN LUNGAU	MUR	UN966187	415.72	297.2	1044.23	1042.20	1940	1041.73	14/3/93	60	-	-	-	14/9/03	490	-
				415.73	297.2			1933	1043.70	13/3/93	-140				14/9/03		
91	TAMSWEG	MUR	VN095198	400.70	501.8	1009.90	1008.30	1940	1006.90	16/3/09	47	-	-	-	14/9/03	335	-
								1933	1007.90	16/3/09	-53				14/9/03	235	-
92	STADL	MUR	227157	380.59	1261.1	-	876.57	1908	876.57	28/3/44	130	-	-	-	3/7/46	454	-
															21/7/31	397	
93	MURAU	MUR	365183	363.71	1453.2	-	794.590	1941	794.59	11/3/47	158	-	-	-	8/7/46	524	-
								1933	796.59						12/5/25	300	-
94	LIND	MUR	549229	341.42	2240.6	-	729.472	1941	729.47	25/2/47	149	-	-	-	15/10/96	470	-
								1933	731.47	25/2/01	-40				15/10/96	270	-
95	ST. GEORGEN	MUR	621290	329.32	2341.7	714	706.95	1940	706.95	18/2/41	160	-	-	-	22/5/38	515	-
								1933	708.95	25/1/25	-40	-	-	-	8/9/16	280	-
								1940	-	25/2/31	177	1931-40	233	-	23/5/38	515	-
96	ZELTWEG	MUR	813260	300.80	2966.4	651.90	646.250	1941	646.25	12/2/22	188	-	-	-	22/5/38	424	-
								1933	647.25	12/2/22	88				12/5/25	290	-
97	NIEDERDORF	MUR	965390	274.28	383.62	579.920	582.84	1922	579.92	4/3/47	142	-	-	-	22/5/38	462	-
								1933	-	21/3/25	145				12/5/25	425	-
98	LEOBEN	MUR	WN070475	254.59	4399.5	538.14	531.10	1941	531.10	27/1/75	191	-	-	-	22/5/38	677	-
								1933	533.10	17/1/75	-29	-	-	-	9/9/16	347	-
								1940	-	21/2/33	194	1931-40	252	-	22/5/38	677	
99	BRÜCK OB MURZ	MUR	198506	235.61	4708.5	481.90	472.50	1940	472.64	29/1/79	120	-	-	-	22/5/38	600	-
								1933	474.64	21/1/79	-30				10/9/16	364	
100	BRÜCK UNTER MURZ	MUR	212511	234.11	6218.2	473.50	468.50	1939	468.12	25/1/09	162	-	-	-	22/5/38	601	-
								1933	470.12	25/1/09	-38	-	-	-	12/5/07	295	
								1940	-	27/1/37	202	1931-40	268	-	22/5/38	601	

NOTES: See page 1, Table 3

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Wash. Dist., Corps of Engineers

RESTRICTED
SECURITY INFORMATION

TABLE 3

SUMMARY OF GAGE DATA - MUR (MURA) RIVER(2)

Gaging Station Number	Gaging Station Name*	River+	U.T.M. Grid Coordinates	River KM(*)	Drainage Area Km3	Approximate Top of Bank m.ü.A. (Meters above Adriatic Sea)	Approximate Stream Bed m.ü.A. (Meters above Adriatic Sea)	Gage Zero Year	Gage Zero m.ü.A.	Minimum Date	Minimum NNW cm	Mean Period	Mean MW cm	Mean MQ m3/sec	Maximum Date	Maximum HHW cm	Maximum HHQ m3/sec
AUSTRIA																	
**101	FROHNLEITEN	MUR	WN235379	210,19	6552.2	420.63	414.72	1941	414.74	18/12/45	124	-	-	-	22/5/38	644	-
								1935	414.74	12/2/30	162	1926-35	222	-	31/5/35	444	
								1933	416.74	7/3/09	-40	-	-	-	9/9/16	300	
102	PEGGAU	MUR	258287	199.30	6705.5	397.55	394.605	1933	395.01	26/1/09	-60	-	-	-	26/5/17	315	-
103	JUDENDORF	MUR	263195	188.74	6911.6	373.30	370.310	1933	371.83	3/2/29	-36	-	-	-	13/5/25	220	-
104	GRAZ	MUR	323152	178.52	7025.0	342.583	340.36	1941	341.01	22/12/46	48	-	-	-	22/5/38	636	-
								1933	345.00	14/3/32	-306	-	-	-	9/9/16	208	-
105	KALSDORF	MUR	372019	166.27	7208.3	314.49	312.746	1941	312.75	29/1/74	105	-	-	-	21/6/44	414	-
								1933	313.61	29/1/74	5	-	-	-	10/9/16	285	
106	WILDON	MUR	395930	155.14	8179.0	291.05	289.285	1941	289.29	15/1/37	100	-	-	-	23/5/38	536	-
								1933	291.29	29/1/09	-93				9/9/16	290	
107	LANDSCHA	MUR	438796	146.03	8347.0	261.25	261.39	1941	258.36	9/3/89	145	-	-	-	23/5/38	590	-
								1933	261.43	9/3/89	-155				12/5/74	287	
108	SPIELFELD	MUR	481736	130.94	9542.6	246.52	246.55	1941	244.30	5/2/82	145	-	-	-	12/5/74	635	-
								1933	246.60	5/2/82	-55				12/5/74	435	
**109	MURECK	MUR	596727	118.55	9780.6	231.0	227.83	1941	227.83	7/11/47	46	-	-	-	4/10/94	670	-
					9780.9			1933	230.83	22/12/27	-212				4/10/94	370	
110	RADKERSBURG	MUR	751708	101.40	-	208.00	205.36	1935	203.15	13/1/29	129	1926-35	224	-	2/5/28	477	-
					10172.4			1933	205.15	13/1/29	-71				9/9/16	343	
YUGOSLAVIA																	
111	VERZEJ	MUR	908603	81.2	-	180.0	-	1923	179.90	1923	-	1923	172	-	-	-	-

NOTES: See page 1, Table 3

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Wash. Dist., Corps of Engineers

RESTRICTED
SECURITY INFORMATION

TABLE 4

MAJOR HYDROELECTRIC STRUCTURES

DRAU (DRAVA) BASIN

Serial(1)	Name	River	U.T.M. Coordinates	Type(2)	Status	Discharge (m^3/sec) Mean	Max.	Storage ($10^6 m^3$)	Hydraulic Head (m)	Power Capacity (10^3KW)	Description Reference Exhibit	Para	Remarks
1	SCHWABECK DAM	DRAU	VM903874	a	Complete 1943	300	5000	25	[illegible]	61	A	6	Fixed weir and 4 movable gates @ 18.75x14
2	LAVAMUEND DAM	DRAU	956654	a	Complete 1944	300	5000	7	9	24	A	7	4 movable gates @ 11x24
3	DRAVOGRAD DAM	DRAU	WM020596	a	Complete 1944	300	5000	11	9	24	A	8	4 movable gates @ 11x24
4	VUZENICA DAM	DRAU	125610	a	Under construction	-	-	-	-	-	A	2d	Concrete poured Nov. 1952
5	FALA DAM	DRAU	350964	a	Complete 1918	235	4600	17	15	30	A	9	Fixed weir and 5 movable gates @ 15x15
6	MARIBOR DAM	DRAU	463576	a	Complete 1950	300	5000	27	14	50	A	10	Fixed weir and 4 movable gates @ 18.75x14
7	PACK DAM	TEIGITSCH (MUR)	WM010020	b	Complete 1932	10	400	5	2[illegible]	1	B	5a	33m arched gravity dam, 3 gate spillway
8	HIERSMANN DAM	TEIGITSCH (MUR)	070030	b	Complete 1950	-	-	7	58	30	B	5e	58m arched gravity dam with spillway
9	DIONYSEN DAM	MUR	174501	a	Complete 1944	75	1700	-	17	11	B	6b	Diversion dam with movable weir and 3 gates @ 15x6; power plant canal 3.75 km long
10	PERNEGG DAM	MUR	232470	a	Complete 1928	140	1800	-	17	18	B	6c	Diversion dam with movable weir and 3 double sluice gates @ 15x11; power plant canal 2.3 km long
11	LAUFNITZDORF DAM	MUR	273422	a	Complete 1931	110	1500	-	19	16	B	6c	Diversion dam with 2 movable cylindrical weirs @ 25x6; power plant canal 7 km long
12	PEGGAU DAM	MUR	258283	a	Complete 1911	60	-	-	12	7	B	[illegible]	Diversion dam with fixed weir and 5 openings - 2 fixed-2 under-logway

NOTES:

1. REFER TO PLATE 1
2. TYPE REFERENCE
   a. Run-of-River
   b. Yearly storage reservoir
   c. Lake storage reservoir
   d. High Head plant
3. ONLY SMALL PORTION OF STORAGE AVAILABLE FOR POWER RELEASE

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Washington District, Corps of Engineers, May 1953

RESTRICTED
SECURITY INFORMATION

RESTRICTED
SECURITY INFORMATION

TABLE 4
MAJOR HYDROELECTRIC STRUCTURES
DRAU (DRAVA) BASIN (Continued)

Serial[1]	Name	River	U.T.M. Coordinates	Type[2]	Status	Discharge (m^3/sec) Mean	Max.	Storage ($10^6 m^3$)	Hydraulic Head (m)	Power Capacity (10^3 kW)	Description Reference Exhibit	Para	Remarks
13	GRATWEIN DAM	MUR	WN49208	a	Complete	76	-	-	-	5	3	6c	Diversion dam with roof weir and 5 gates
14	LEBRING DAM	MUR	WM405911	a	Complete 1911	95	-	-	7	4	3	6c	Diversion weir with 5 gates; power canal 1 km long
15	ARNOLDSTEIN DAM (Gailwerk-Schuett)	GAIL	VM047570	a	Complete	50	-	-	17	5	A	11b	Diversion dam with 4 gates @ 12x4.7
16	RAINWERK DAM	GURK	552640	a	Complete 1925	28	-	-	15	4	A	11e	
17	FORSTSEEWERK RESERVOIR(3)	GURK	292645	c	Complete 1937	4	-	5	160	2	A	11c	
18	LASSACH POWER PLANT	MALLNITZ (MOELL)	UN623032	d	Complete	4	66	-	138	2	A	11f	Operated by Austrian RR
19	MALLNITZ POWER PLANT	MOELL	UN625091	a	Complete	5	-	-	-	20	A	11f	Operated by Austrian RR
20	FLEISSBACH POWER PLANT	MOELL	UN530120	d	Complete	1	29	-	331	3	A	11f	Auxiliary plant during KAPRUN construction
21	MARGARITZE RESERVOIR	MOELL	340150	b	Complete	-	-	3.1	77	-	A	11f	2 dams to furnish storage for the MOELL Transfer Conduit to KAPRUN
22	KALSERBACH RESERVOIR	KALSERBACH (ISEL)	175010	b	Complete 1950	6	-	0.1	57	6	A	11g	
23	FAAKER SEE RESERVOIR(3)	GAIL	VM165506	c	Planned	-	-	30	-	-	A	11c	
24	WEISSENSEE POWER PLANT(3)	DRAU	UM766733	c	Under construction	14	-	133	-	-	A	11d	To be built in 3 stages including 1 dam and storage reservoir
25	INNERGSCHLOSS RESERVOIR	ISEL	UM190521	b	Proposed	-	-	90	-	-	A	11g	
26	TAURENTAL RESERVOIR	ISEL	195522	b	Proposed	-	-	120	-	30	A	11g	
27	DORFERTAL RESERVOIR	ISEL	210521	b	Proposed	-	-	25	98	120	A	11g	To be retained by 140m DABERKLAMM DAM
28	POELLAND POWER PLANT	ISEL	UM270698	a	Proposed	-	-	-	-	30	A	11g	
29	REISSECK-KREUZECK P.P.(3)	MOELL	260970	d	Under construction	-	-	18	-	120	A	11g	6 lakes, 9 streams, 3 reservoirs

NOTES:
SEE PAGE 1

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SECURITY INFORMATION

Prepared by Military Hydrology Branch
Washington District, Corps of Engineers, May 1953

TABLE 5
INUNDATION EFFECTS OF STILLWATER BARRIERS
DRAU (DRAVA RIVER)

Reach of DRAU River	Site No.	DRAU River Km	A.M.S. Map No. Series/Sheet	UTM Grid	Location & Description	Dimensions of Inundated Area: Pool Elev. m.ü.A.	Height above MW (m)	Length Km	Average Width Km	Average Depth m	Area Km^2	Volume $10^6 m^3$	Remarks
LIENZ (Km 369)-VILLACH (Km 257)		No suitable sites for stillwater obstacles											River lies generally in deep narrow valleys. Banks generally high and abrupt.
VILLACH-GURK R. (Km 188)	1	212.5	M791/14B-I	4354	Rd. Br. nr, KAPPLE	430	5	2.5	0.5	Less than 1	1.5	1.5	Flooding confined to right bank.
		(1) Additional sites considered unsuitable due to high banks. (2) Swamps near KLAGENFURT north of left bank may be supplemented to form barrier parallel to river 5-8 Km north of left bank.											
GURK R.-MARIBOR (Km 72)		(1) No suitable sites. (2) River flows through gorge with very high steep sides.											
MARIBOR-D. MIHOLJAC (Km -190)	2	43.72	M702/14-IV	670410	PTUJ RR Br.	222	3.3	Limited local flooding.					Effective width of River increased to 500-600 m by swamping area between meander channels.
	3	13.3	M702/14-I	886397	ORMOZ Rd. Br.	192	4.0	Little or no overbank flooding.					Effective width of River increased to 500-750 m by swamping area between meanders.
	4	-8.9	M702/15-IV	047310	VARAZDIN Rd. Br.	169	2	4	1-2.5	Less than 1	8	8	Confined mainly to right bank.
	5	-63	M702/16-III	494230	BOTOVO RR Br.	130	9	6	5-7	Less than 1	35	35	Elevation of top of bank is approximately 126 m.ü.A.
	6	-114	M702/32-IV	884912	BARČS RR Br.	107	6	Little or no overbank flooding.					Flooding of 15 km long meander bed starting 12 km upstream from bridge.
	7	-148	M773/5660W	220732	RR Br.	100	4	Little or no overbank flooding.					Flooding of old meander beds for distance of 18-20 km upstream.
	8	-190	M773/5660E	824740	D. MILHOLJAC RR Br.	93	3	5	3-5	Less than 1	20	20	

May be possible to utilize swamp areas north of LEGRAD & BOTOVO as effective drainage obstacles.

Prepared by: Military Hydrology R&D Branch
Washington Dist., Corps of Engineers, May 1953

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TABLE 5 (CONTINUED)
INUNDATION EFFECTS OF STILLWATER BARRIERS
MUR (MURA) RIVER)

Reach of MUR River	Site No.	MUR River Km.	A.M.S. Map No. Series/Sheet	UTM Grid	Location & Description	Dimensions of Inundated Area: Pool Elev. m.ü.A.	Height above MW (m)	Length km	Average width km	Average Depth m	Area km^2	Volume 10^6 m^3	Remarks
SOURCE-RADKERSBURG (Km 101)		No suitable sites for stillwater obstacles											River lies generally in narrow valley with steep stream gradient and abrupt high banks.
RADKERSBURG-DRAU R. (Km 0)	9	100.6	M702/6-III	762706	RR Br. RADKERSBURG	210.0	5.4	7	3-4	1.1	17	18	
		100 to 50	LEDAVA & DOBEL RIVERS run in embanked sections roughly parallel and 4-10 km north of the MUR. Area between these rivers and the MUR is apparently flat and probably subject to flooding.										
	10	52.7	M707/7-III	108524	RR Br. MURSKO-SREDIŠČE	Bank elevation approximately 165 m.ü.A. (MW + 3 m). Any blocking above this elevation would probably cause considerable flooding between LEDAVA & MUR Rivers. (See note above).							
	11	9.0	M773/5450W	005357	RR Br. nr. KOTORIBA	135	5	Will cause flooding of old meander beds 3-4 km upstream.					

Prepared by: Military Hydrology R&D Branch
Washington Dist., Corps of Engineers, May 1953

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TABLE 6
SUMMARY OF EFFECTS OF ARTIFICIAL FLOOD WAVES AND FLOW VARIATIONS
DRAU (DRAVA) RIVER BASIN

Flood No.	Type of Outflow	Location	River	River Km.	Elevation of Peak Flow (m.ü.A.)	Peak Discharge (m³/sec) Initial	Increase	Crest	River Depth (m) Initial	Increase	Crest	Ove. flow Depth at Crest (m)	River Width (Km) Initial	Crest	Mean Surface Velocity (m/sec) Initial	Crest	(a) Time (hrs.) Start of Rise	Crest	Duration above base flow (hrs.)
1	Flow Variation	SCHWABECK DAM	DRAU	153	-	275	8225	8500	-	-	-	-	-	-	-	-	0	0	4
	(All Reservoirs	LAVAMUEND DAM	"	147	-	275	6325	6600	-	-	-	-	-	-	-	-	0	0	4
	initially full;	DRAVOGRAD DAM	"	136	-	275	6025	6300	-	-	-	-	-	-	-	-	0	0	5
	open all gates)	VUZENICA DAM	"	124	-	275	8225	8500	-	-	-	-	-	-	-	-	0	0	6
		FALA DAM	"	91	-	275	8225	8500	-	-	-	-	-	-	-	-	2	2	8
		MARIBOR DAM	"	76	259.5	275	8225	9500	2.4	7.1	9.5	-	0.5	0.5	-	4.7	2	2	10
		PTUJ	"	44	222.1	380	5340	5720	3.6	3.4	7.0	2.0	0.5	1.5-4.0	2.1	3.3	4	6	12
		ORMOZ	"	12	194.5	400	4960	5360	2.2	5.3	7.5	4.5	0.5	2.0-5.0	2.3	3.3	6	10	13
		BARČS	"	-111	105.3	600	3410	4010	2.4	3.3	5.7	Bankfull	0.5	0.5-1.0	2.7	4.1	15	20	16
		D. MIHOLJAC	"	-190	92.9	660	1940	2600	1.9	2.9	4.8	Bankfull	0.5	0.5	1.0	1.1	34	42	18
		MOUTH OF DRAVA	"	-262	-	700	1400	2100	-	-	-	(b) (c)	0.5	3.0-4.0	-	-	52	62	20
2	Flow Variation	SCHWABECK DAM	"	153	-	275	1850	2125	-	-	-	-	-	-	-	-	0	0	15
	(All Reservoirs	LAVAMUEND DAM	"	147	-	275	1405	1680	-	-	-	-	-	-	-	-	0	0	15
	initially full;	DRAVOGRAD DAM	"	136	-	275	1205	1480	-	-	-	-	-	-	-	-	0	0	15
	open 1 gate ea.	VUZENICA DAM	"	124	-	275	1875	2150	-	-	-	-	-	-	-	-	0	0	27
	except FALA,	FALA DAM	"	91	-	275	4175	4450	-	-	-	-	-	-	-	-	4	4	29
	where 2 gates	MARIBOR DAM	"	76	255.9	275	2275	2550	2.4	3.5	5.9	-	0.5	0.5	-	-	4	4	30
	are opened)	PTUJ	"	44	220.6	380	2020	2400	3.6	1.9	5.5	0.6	0.5	1.5-2.0	2.1	3.0	8	10	31
		ORMOZ	"	12	191.9	400	1800	2200	2.2	2.7	4.9	1.9	0.5	2.0-5.0	2.3	3.1	10	14	32
		BARČS	"	-111	104.4	600	1300	1900	2.4	2.4	4.8	Bankfull	0.5	0.5	2.7	3.8	18	26	35
		D. MIHOLJAC	"	-190	92.0	660	1040	1700	1.9	2.0	3.9	Bankfull	0.5	0.5	1.0	1.1	36	45	38
		MOUTH OF DRAVA	"	-262	-	700	870	1570	-	-	-	(b) (c)	-	-	-	-	52	62	40
3	Flow Variation	SCHWABECK DAM	"	153	-	275	8225	8500	-	-	-	-	-	-	-	-	0	0	4
	(Open 4 gates with	LAVAMUEND DAM	"	147	-	275	3625	3900	-	-	-	-	-	-	-	-	0	1	5
	SCHWABECK full;	DRAVOGRAD DAM	"	136	-	275	2500	2775	-	-	-	-	-	-	-	-	1	2	6
	all others open	VUZENICA DAM	"	124	-	275	2075	2350	-	-	-	-	-	-	-	-	2	3	6
	and empty or	FALA DAM	"	91	-	275	1625	1900	-	-	-	-	-	-	-	-	4	6	6
	destroyed)	MARIBOR GAGE	"	73	250.5	300	1500	1800	0.9	2.7	3.6	-	0.5	0.5	1.9	3.1	5	8	7
		PTUJ	"	44	220.2	380	1340	1720	3.6	1.5	5.1	0.2	0.5	1.5-2.0	2.1	2.9	8	10	7
		ORMOZ	"	12	191.3	400	1220	1620	2.2	2.1	4.3	1.3	0.5	2.0-4.0	2.3	3.0	10	14	8
		BARČS	"	-111	103.7	600	690	1290	2.4	1.7	4.1	Bankfull	0.5	0.5	2.7	3.5	22	26	9
		D. MIHOLJAC	"	-190	91.0	660	400	1060	1.9	1.0	2.9	Within banks	0.5	0.5	1.0	1.1	38	46	13
		MOUTH OF DRAVA	"	-262	-	700	330	1030	-	-	-	(b) (c)	-	-	-	-	53	62	16

FOOTNOTES:
(a) Zero Time=opening of SCHWABECK Gates
(b) Considerable flooding below Km -244
(c) Estimated by comparison with 1926 flood data
(d) Kilometers above mouth of MUR RIVER

Prepared by Military Hydrology R&D Branch
Washington Dist., Corps of Engineers, May 1953

TABLE 6 (CONTINUED)
SUMMARY OF EFFECTS OF ARTIFICIAL FLOOD WAVES AND FLOW VARIATIONS
DRAU (DRAVA) RIVER BASIN

Flood No.	Type of Outflow	Location	River	River Km.	Elevation of Peak Flow (m.u.A.)	Peak Discharge (m^3/sec) Initial	Peak Discharge Increase	Peak Discharge Crest	River Depth (m) Initial	River Depth Increase	River Depth Crest	Overflow Depth at Crest (m)	River Width (Km) Initial	River Width Crest	Mean Surface Velocity (m/sec) Initial	Mean Surface Velocity Crest	(a) Time (hrs.) Start of Rise	(a) Time (hrs.) Crest	Duration above base flow (hrs.)
4	Flow Variation (Open 1 gate with SCHWABECK full; all others open and empty or destroyed)	SCHWABECK DAM	DRAU	153	-	275	1850	2125	-	-	-	-	-	-	-	-	0	0	15
		LAVAMUEND DAM	"	147	-	275	1450	1725	-	-	-	-	-	-	-	-	0	2	15
		DRAVOGRAD DAM	"	136	-	275	1275	1550	-	-	-	-	-	-	-	-	1	3	16
		VUZENICA DAM	"	124	-	275	1150	1425	-	-	-	-	-	-	-	-	2	4	17
		FALA DAM	"	91	-	275	960	1235	-	-	-	-	-	-	-	-	4	7	18
		MARIBOR GAGE	"	73	249.1	300	900	1200	0.9	1.3	2.2	-	0.5	0.5	1.9	2.9	6	10	19
		PTUJ	"	44	219.8	380	820	1200	3.6	1.1	4.7	Bankfull	0.5	0.5-1.0	2.1	2.8	9	13	19
		ORMOZ	"	12	190.7	400	770	1170	2.2	1.3	3.7	0.7	0.5	2.0-4.0	2.3	2.8	12	17	20
		BARČS	"	-111	103.4	600	580	1180	2.4	1.4	3.8	Bankfull	0.5	0.5	2.7	3.4	24	31	20
		D. MIHOLJAC	"	-190	91.0	660	400	1060	1.9	1.0	2.9	Within banks	0.5	0.5	1.0	1.1	42	50	22
		MOUTH OF DRAVA	"	-262	-	700	330	1030	-	-	-	(b) (c)	0.5	2.0-3.0	-	-	54	63	28
5	Major Floodwave (10x20m Trapezoidal Breaches in PACK and HIERSMANN DAMS)	PACK DAM	TEIGITSCH	(d) 223	-	0	2500	2500	-	-	-	-	-	-	-	-	0	0	4
		HIERSMANN DAM	"	(d) 211	-	0	2500	2500	-	-	-	-	-	-	-	-	1	1	5
		WILDON	MUR	(d) 155	294.8	130	850	980	2.0	3.5	5.5	0.8	0.1	0.2	1.6	2.9	7	9	6
		MURECK	"	(d) 118	231.6	150	683	833	1.9	1.9	3.8	Bankfull	0.1	0.3	1.3	2.5	11	13	7
		MOUTH OF MUR	"	(d) 0	-	200	475	675	-	-	-	-	-	-	-	-	20	23	10
		BARČS	DRAU	-111	102.9	600	380	980	2.4	0.9	3.3	Within banks	0.5	0.5	2.7	3.2	23	27	11
		D. MIHOLJAC	"	-190	90.7	660	205	865	1.9	0.7	2.6	" "	0.5	0.5	1.0	1.1	43	48	12
6	Major Floodwave (20x20m Trapezoidal Breach in PACK and HIERSMANN DAMS)	PACK DAM	TEIGITSCH	(d) 223	-	0	4050	4050	-	-	-	-	-	-	-	-	0	0	2
		HIERSMANN DAM	"	(d) 211	-	0	4050	4050	-	-	-	-	-	-	-	-	1	1	4
		WILDON	MUR	(d) 155	295.1	130	930	1060	2.0	3.8	5.8	1.1	0.1	0.2	1.6	3.0	7	9	6
		MURECK	"	(d) 118	231.7	150	760	910	1.9	2.0	3.9	Bankfull	0.1	0.3	1.3	2.6	11	13	7
		MOUTH OF MUR	"	(d) 0	-	200	510	710	-	-	-	-	-	-	-	-	20	23	10
		BARČS	DRAU	-111	102.9	600	395	995	2.4	0.9	3.3	Within banks	0.5	0.5	2.7	3.2	23	27	11
		D. MIHOLJAC	"	-190	90.7	660	215	875	1.9	0.7	2.6	" "	0.5	0.5	1.0	1.1	43	48	12

FOOTNOTES:
(a) Zero Time: opening of SCHWABECK Gates
(b) Considerable flooding below KM -244
(c) Estimated by comparison with 1926 flood data
(d) Kilometers above mouth of MUR RIVER

Prepared by Military Hydrology R&D Branch
Washington Dist., Corps of Engineers, May 1953

TABLE 7

LOAD CHARACTERISTICS OF U. S. ARMY FLOATING BRIDGES

LOAD CLASS (TONS) OF FLOATING BRIDGES (by VELOCITY, by TYPE, by RELATIVE CROSSING SAFETY)

Type	Status (1952)	Relative Crossing Safety: Safe — Maximum Surface Velocity fps / m/sec						Caution — Maximum Surface Velocity fps / m/sec					Risk — Maximum Surface Velocity fps / m/sec					Velocity to destroy with no Load (fps)
		0	3	5	7	9	11	3	5	7	9	11	3	5	7	9	11	
		0	0.92	1.5	2.1	2.7	3.4	0.92	1.5	2.1	2.7	3.4	0.92	1.5	2.1	2.7	3.4	
M2 Assault Boat Bridge (Normal Construction)	Standard	8	8	6	5	-	-	8	6	5	-	-	9	7	6	-	-	10
M2 Assault Boat Bridge (Reinforced Construction)	Standard	13	13	9	7	-	-	13	11	8	-	-	14	12	9	-	-	9
Widened Steel Treadway Br.	Standard	50	50	50	40	30	15	50	50	45	35	20	55	55	50	45	30	14
50-T (Divisional Airborne)	Standard	50	45	35	30	10	-	50	40	35	15	-	55	50	45	25	-	12
M4 (Normal Construction) (15' Bay)	Standard	55	55	55	55	45	30	60	60	60	50	40	65	65	65	55	45	16
Steel Class 60 Floating Br.	Standard	60	60	60	55	50	15	65	65	60	55	30	75	75	70	65	45	-
M4 (Reinforced Construction) (7½' Bay)**	Standard	95*	95*	95*	95*	70	40	100*	100*	100*	85	55	105*	105*	105*	100	70	16
M4-T6	Developmental	55	50	50	50	35	15	(No further data)										-
Aluminum Class 60 Floating Br.	Developmental	70	70	70	65	55	45	(No further data)										

*Tank data (limited by width of roadway and width of tank)
**(100% reinforced, with full Pontoons)

SOURCES:
(1) Ref 61
(2) Ref 62
(3) Misc data Engr. R&D Lab. Engr. Center, Ft. Belvoir

Prepared by Military Hydrology R&D Branch
Washington District, Corps of Engineers, Nov. 1952

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PLATES

1. General Map
2. Physiographic Diagram
3. General Profile
4. Stream Profiles
   a. DRAU River, LIENZ-VUZENICA
   b. DRAU River, VOLKERMARKT-BOTOVO
   c. DRAU River, BOTOVO-DANUBE R.
   d. MUR River, MUR FALLS-BRUCK O.
   e. MUR River, BRUCK O.M.-DRAU R.
5. Velocity, Depth, Discharge Profile
6. Mean Monthly Stages
   a. Km 362-Km 257
   b. Km 250-Km 147
   c. Km 136-Km 28
7. Stage and Discharge Duration Curves
   a. MARIBOR-D. MIHOLJAC
   b. FEDERAUN-RADKERSBURG
8. Discharge and Velocity Rating Curves
   a. LAVANT-VILLACH
   b. ROSEGG-NEUBRUCKE
   c. PTUJ & ORMOZ
   d. BARCS & D. MIHOLJAC
9. Sketches of Dams
   a. SCHWABECK & LAVAMUND
   b. FALA & MARIBOR
   c. ARNOLDSTEIN & PERNEGG
   d. PACK & HIERSMANN
10. Inundation by Still-water Barriers
    a. LIENZ-FALA
    b. FALA-MOUTH
11. Reservoir Storage & Discharge Ratings
    a. SCHWABECK-VUZENICA
    b. FALA, MARIBOR, PACK & HIERSMANN
12. Crest Profiles, Artificial Floods
13. Stage Hydrographs, Artificial Floods
    a. MARIBOR & ORMOZ
    b. WILDON & D. MIHOLJAC

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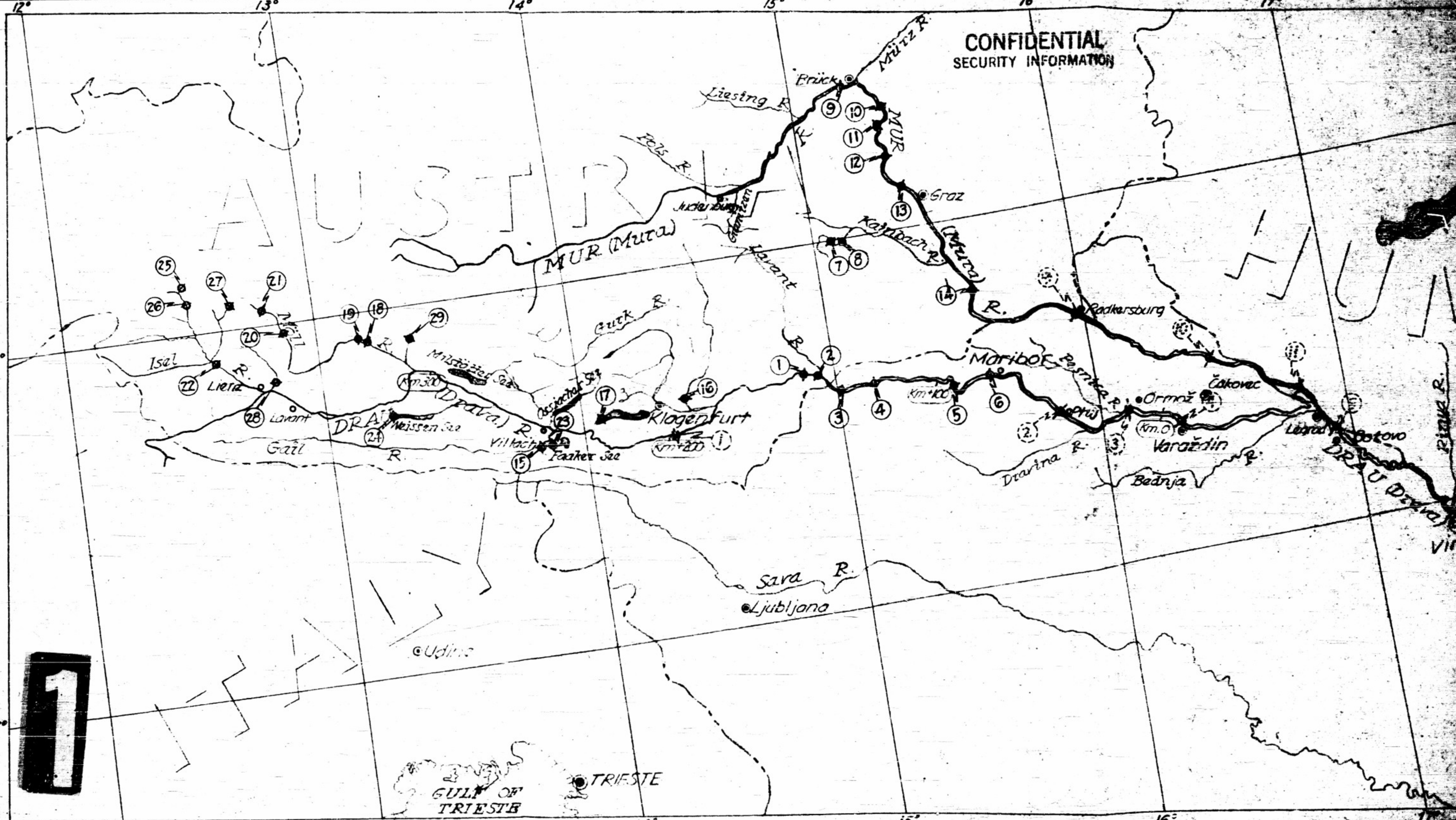

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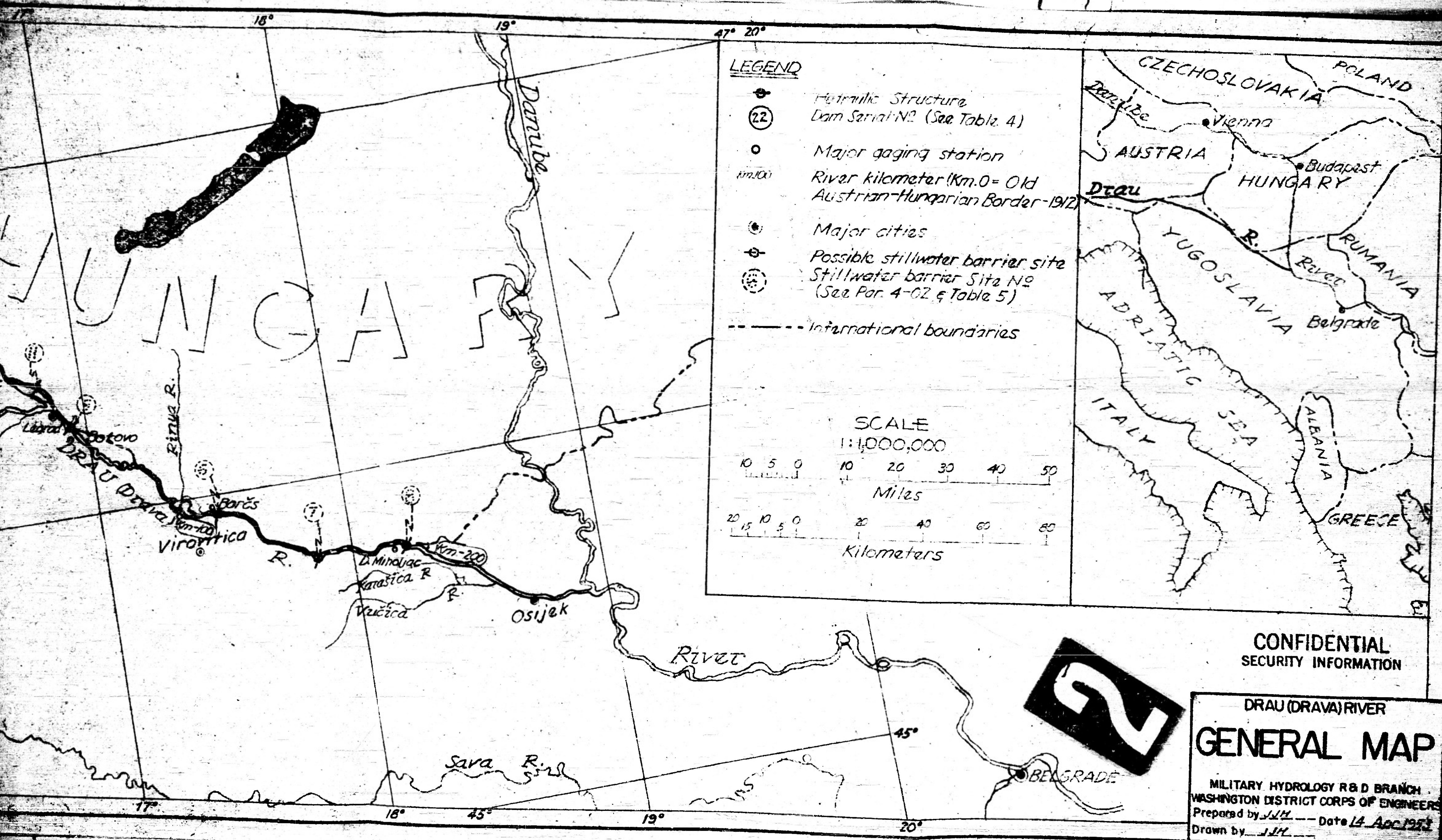

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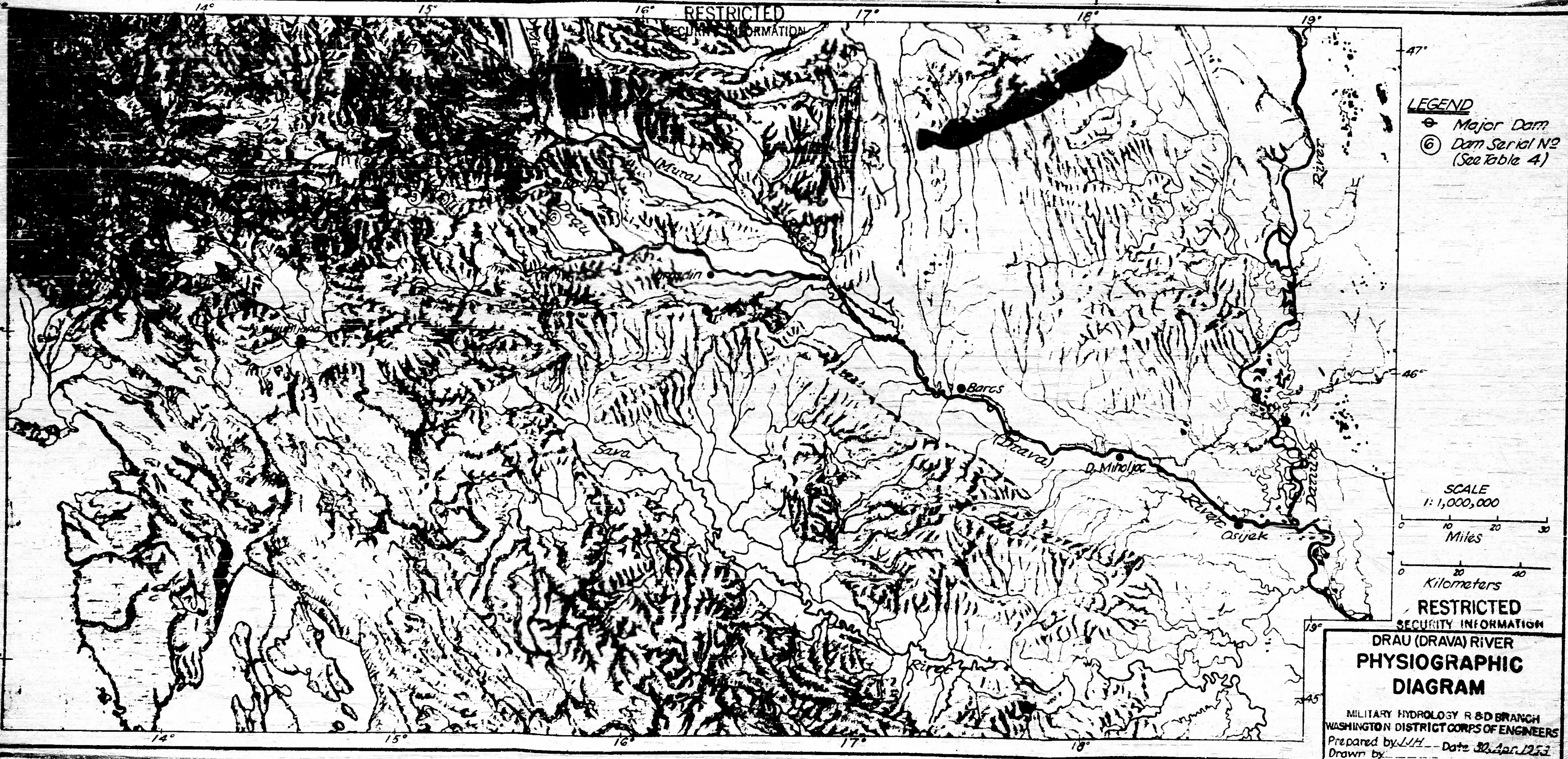
DRAU (DRAVA) RIVER

GENERAL MAP

MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JJH Date 14 Apr 1953
Drawn by JJH

PLATE 2



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DRAU (DRAVA) RIVER
PHYSIOGRAPHIC DIAGRAM

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by J.J.H. Date 30 Apr. 1953
Drawn by

PLATE 2

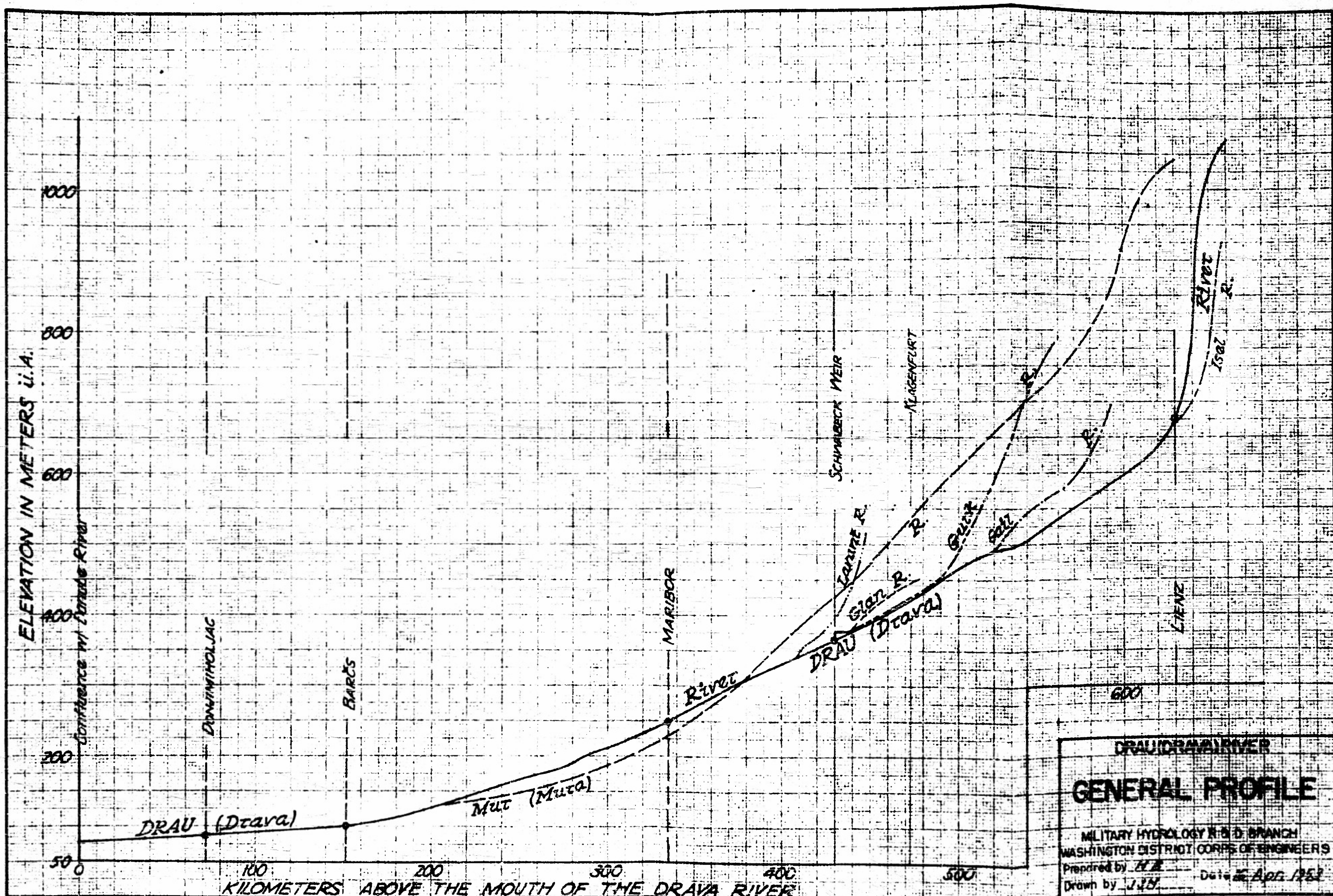
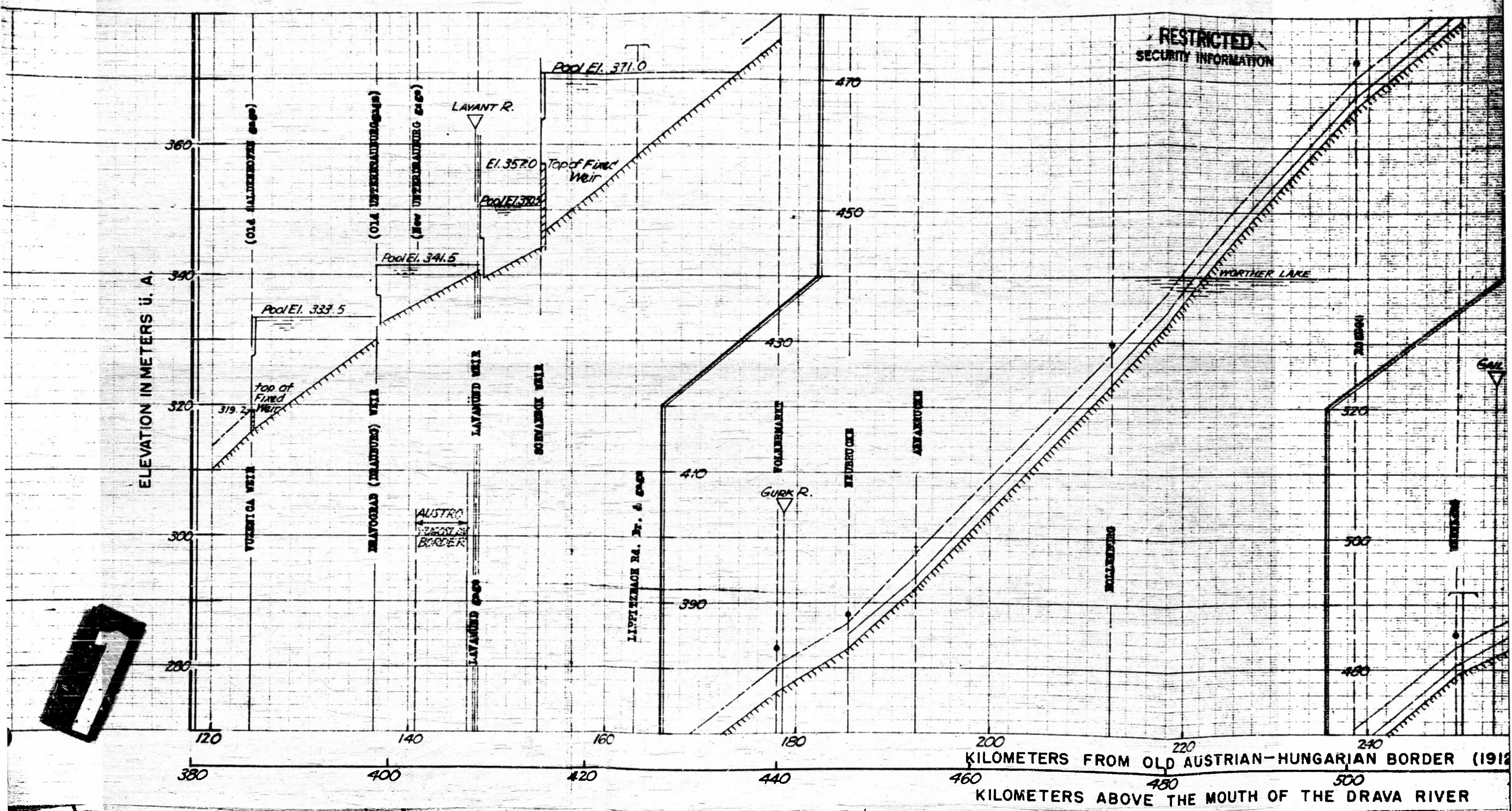

ELEVATION IN METERS ü.A.
1000
800
600
400
200
50
0
100
200
300
400
500
600
KILOMETERS ABOVE THE MOUTH OF THE DRAVA RIVER
DRAU (Drava)
Mur (Mura)
River
DRAU (Drava)
Glan R.
Lanine R.
R.
Gurk
Gail
R.
R.
River
Isel R.
MARIBOR
SCHWABECK WEIR
KLAGENFURT
LIENZ
BARCS
DONJI MIHOLJAC
DRAU (DRAVA) RIVER
GENERAL PROFILE
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by H.R.
Drawn by J.J.H.
Date 25 Apr. 1952

PLATE 3



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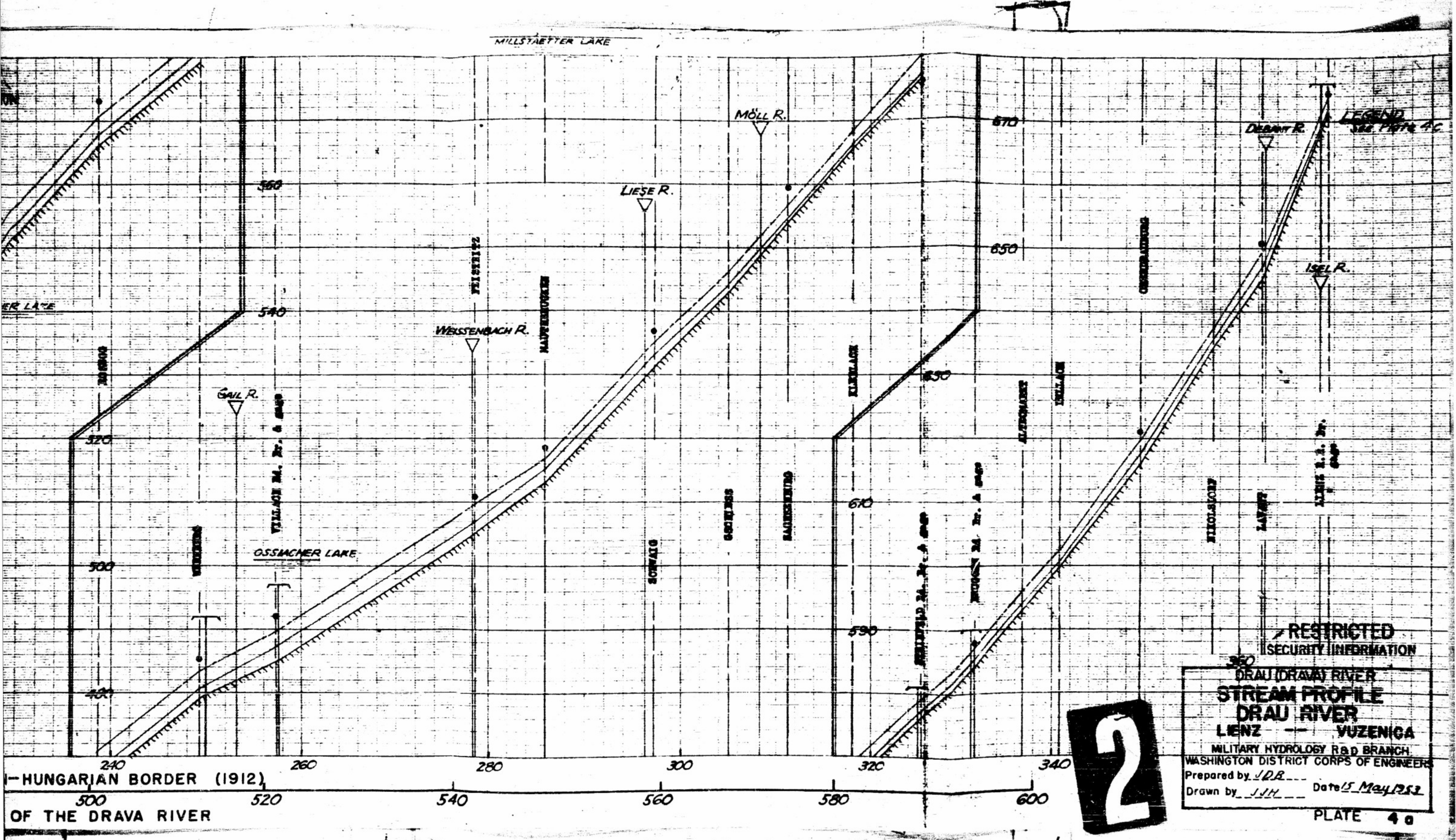
ELEVATION IN METERS Ü. A.
Pool El. 371.0
LAVANT R.
El. 357.0
Top of Fixed Weir
Pool El. 350.5
Pool El. 341.5
Pool El. 333.5
top of Fixed Weir
319.2
AUSTRO
BORDER
GURK R.
WÖRTHER LAKE
GAIL
(Old UNTERDRAUBURG gage)
(New UNTERDRAUBURG gage)
VUZENICA WEIR
DRAVOGRAD (DRAUBURG) WEIR
LAVAMÜND WEIR
LAVAMÜND gage
SCHWABECK WEIR
LIPPITZBACH Rd. Br. & gage
360
340
320
300
280
470
450
430
410
390
320
300
480
120
140
160
180
200
220
240
380
400
420
440
460
480
500
KILOMETERS FROM OLD AUSTRIAN-HUNGARIAN BORDER (1912
KILOMETERS ABOVE THE MOUTH OF THE DRAVA RIVER


MILLSTAETTER LAKE
MÖLL R.
LIESE R.
WEISSENBACH R.
GAIL R.
OSSIACHER LAKE
DEBANT R.
ISEL R.
LEGEND
See Plate 4c
-HUNGARIAN BORDER (1912)
OF THE DRAVA RIVER
RESTRICTED
SECURITY INFORMATION
DRAU (DRAVA) RIVER
STREAM PROFILE
DRAU RIVER
LIENZ — VUZENICA
MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JDR
Date 15 May 1953
Drawn by JJH
PLATE 4a
2

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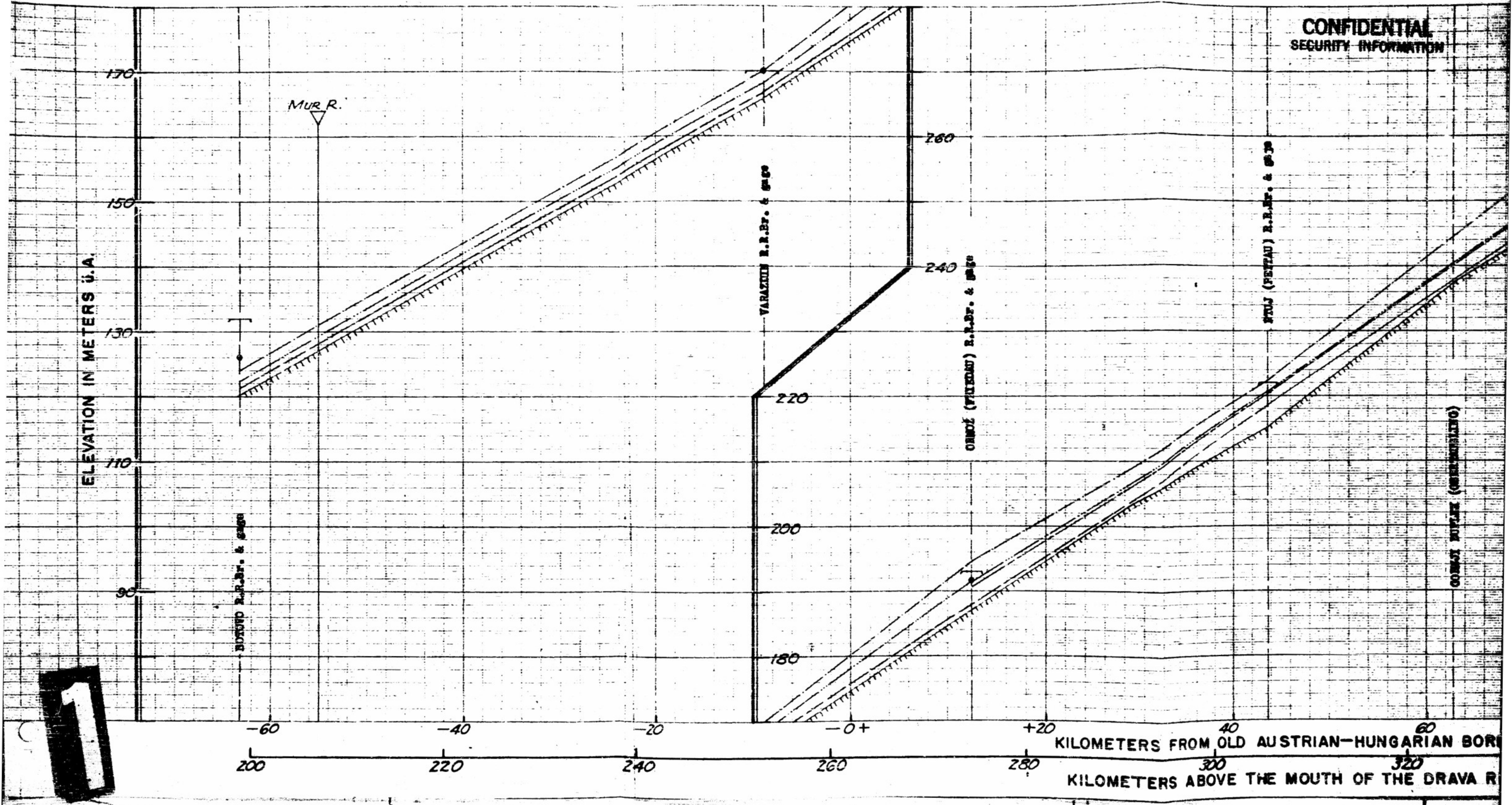
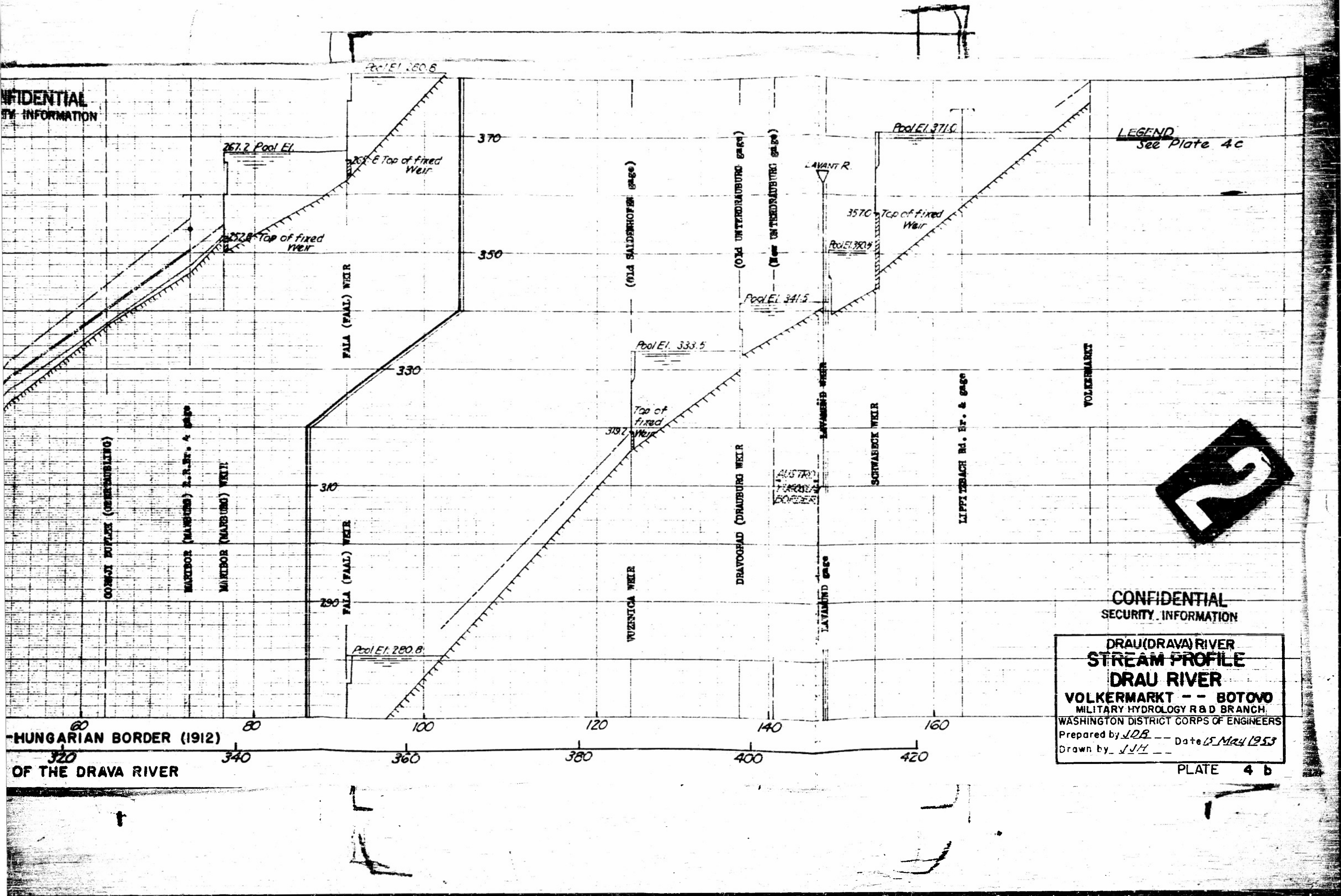
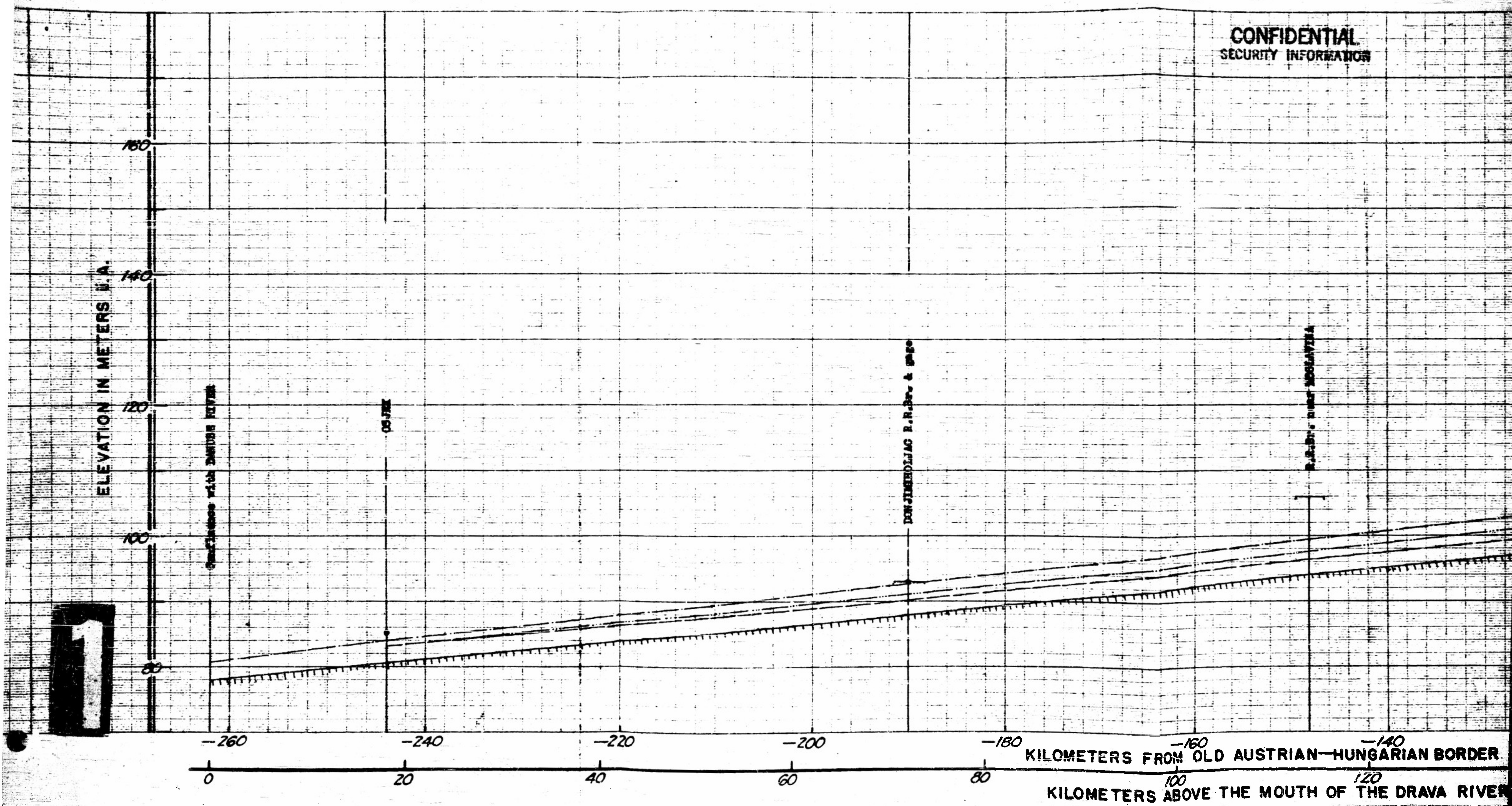
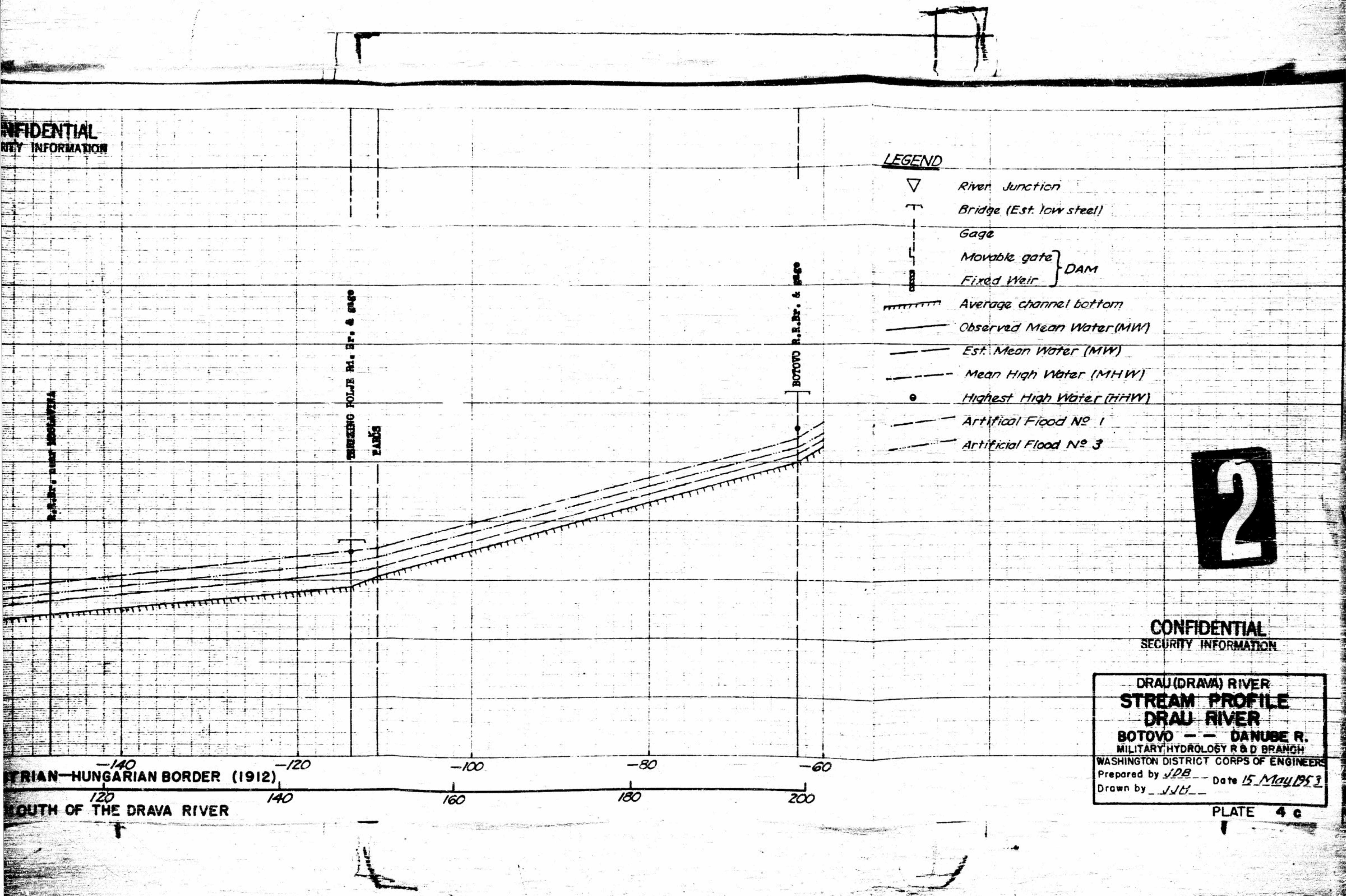
SECURITY INFORMATION



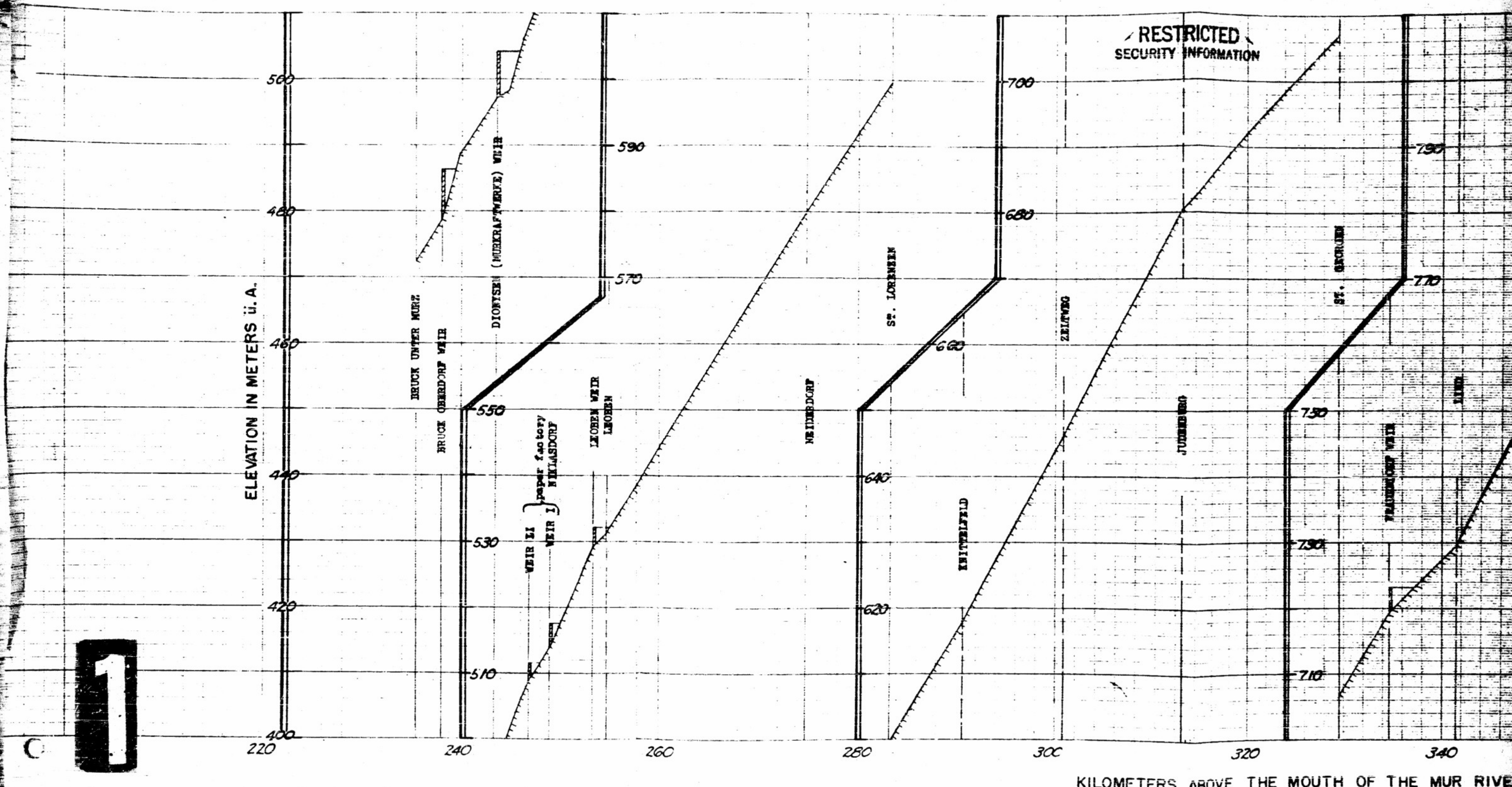


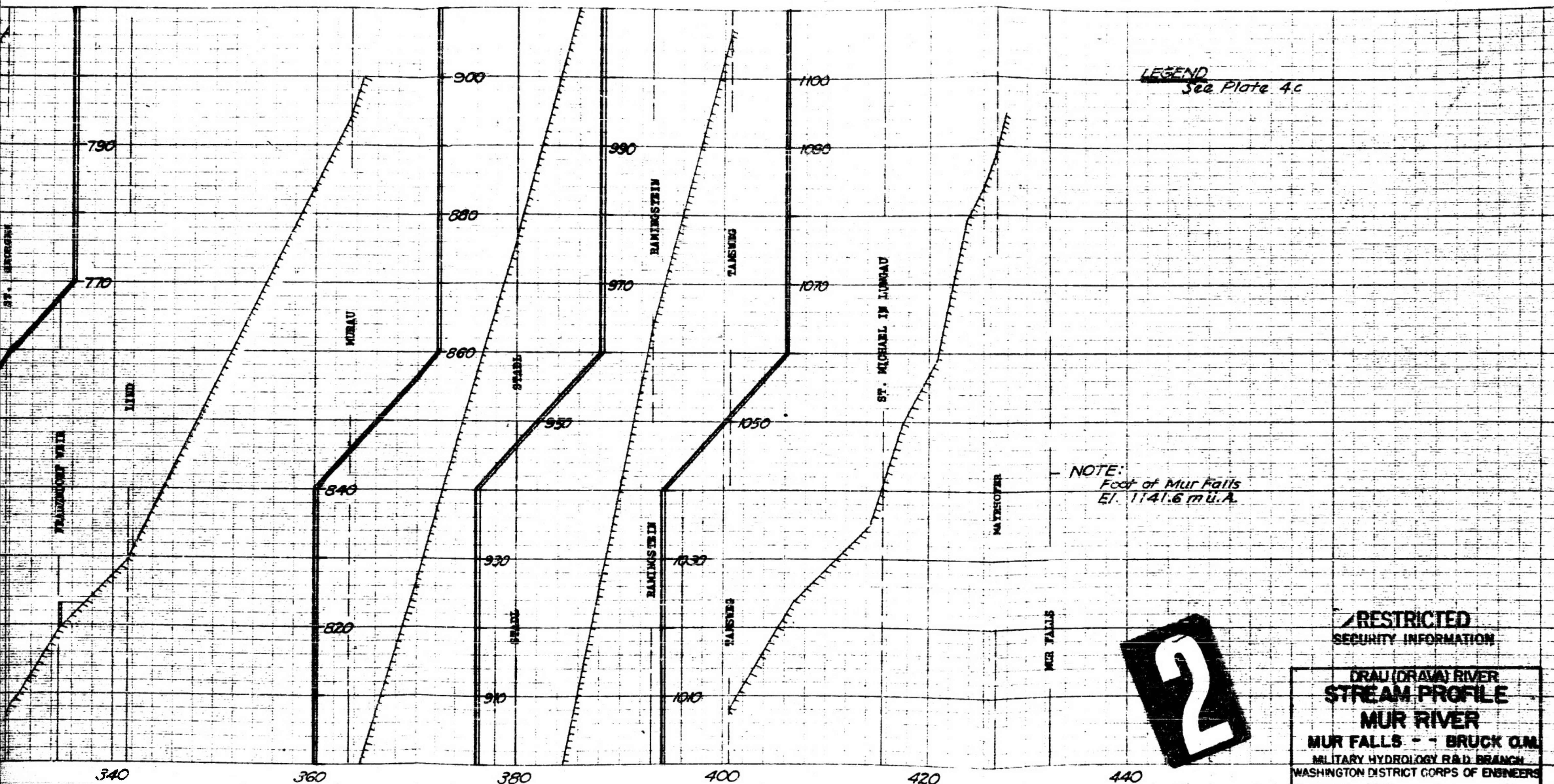
CONFIDENTIAL
SECURITY INFORMATION
Pool El. 280.6
267.2 Pool El.
265.8 Top of fixed Weir
252.8 Top of fixed Weir
370
350
330
310
290
Pool El. 333.5
Top of fixed Weir
319.7
Pool El. 341.5
Pool El. 371.0
357.0 Top of fixed Weir
Pool El. 350.4
LAVANT R.
LEGEND
See Plate 4c
Pool El. 280.8
FALA (FAAL) WEIR
VUZENICA WEIR
DRAVOGRAD (DRAUBURG WEIR
LAVAMUND WEIR
LAVAMUND gage
SCHWABECK WEIR
LIPPITZBACH Rd. Br. & gage
VOLKERMARKT
AUSTRO YUGOSLAV BORDER
60
80
100
120
140
160
-HUNGARIAN BORDER (1912)
320
340
360
380
400
420
OF THE DRAVA RIVER
2
CONFIDENTIAL
SECURITY INFORMATION
DRAU(DRAVA) RIVER
STREAM PROFILE
DRAU RIVER
VOLKERMARKT -- BOTOVO
MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JDB Date 15 May 1953
Drawn by JJH
PLATE 4 b


ELEVATION IN METERS U.A.
160
140
120
100
80
Confluence with DANUBE RIVER
OSIJEK
DONJI MIHOLJAC R.R.Br. & gage
R.R.Br.
-260
-240
-220
-200
-180
-160
-140
KILOMETERS FROM OLD AUSTRIAN—HUNGARIAN BORDER
0
20
40
60
80
100
120
KILOMETERS ABOVE THE MOUTH OF THE DRAVA RIVER


NFIDENTIAL
RITY INFORMATION
LEGEND
River Junction
Bridge (Est. low steel)
Gage
Movable gate
Fixed Weir
DAM
Average channel bottom
Observed Mean Water (MW)
Est. Mean Water (MW)
Mean High Water (MHW)
Highest High Water (HHW)
Artifical Flood Nº 1
Artificial Flood Nº 3
POLJE Rd. Br. & gage
BOTOVO R.R.Br. & gage
-140
-120
-100
-80
-60
TRIAN—HUNGARIAN BORDER (1912)
120
140
160
180
200
MOUTH OF THE DRAVA RIVER
2
CONFIDENTIAL
SECURITY INFORMATION
DRAU (DRAVA) RIVER
STREAM PROFILE
DRAU RIVER
BOTOVO — — DANUBE R.
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JDB Date 15 May 1953
Drawn by JJH
PLATE 4 c

RESTRICTED
SECURITY INFORMATION



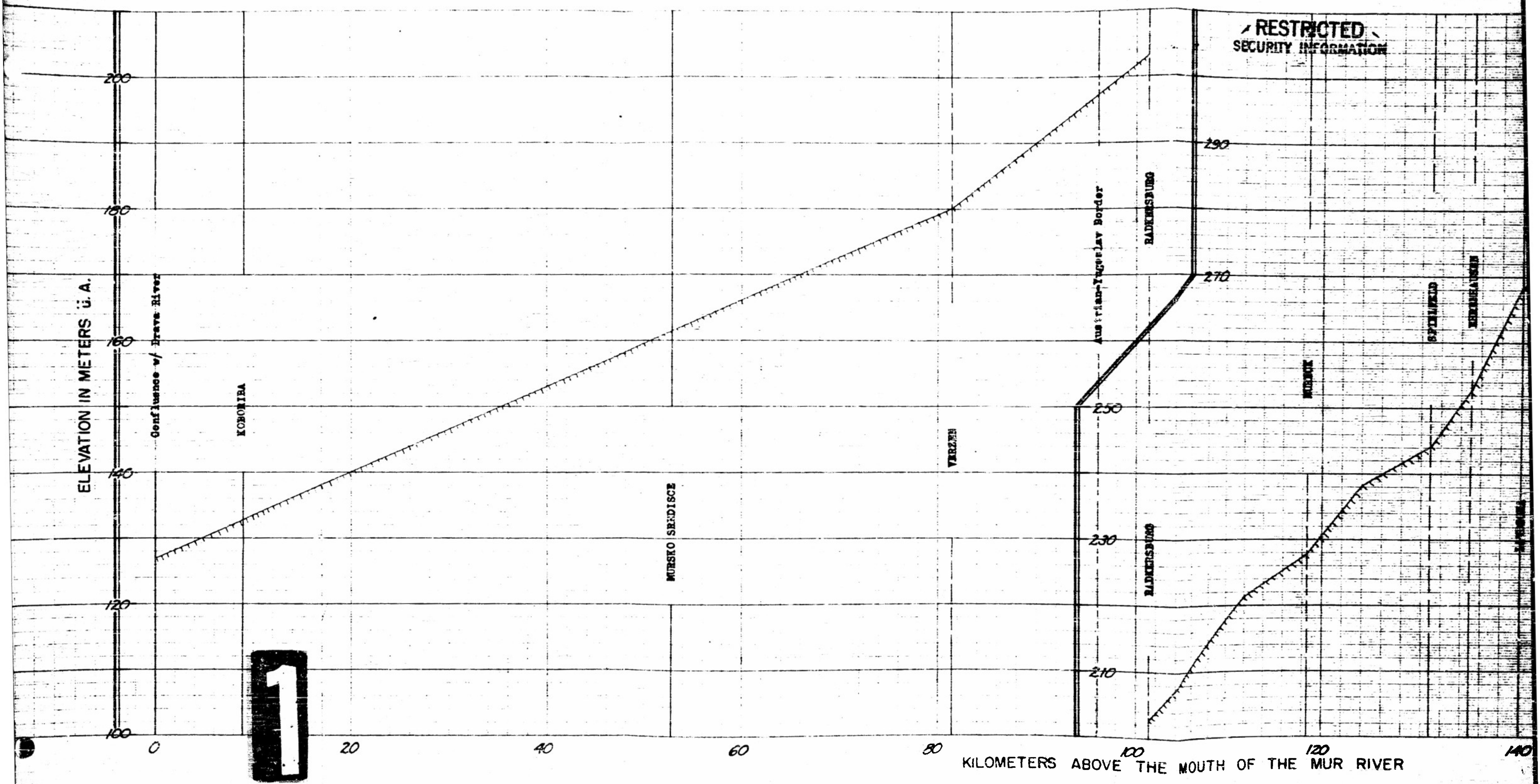


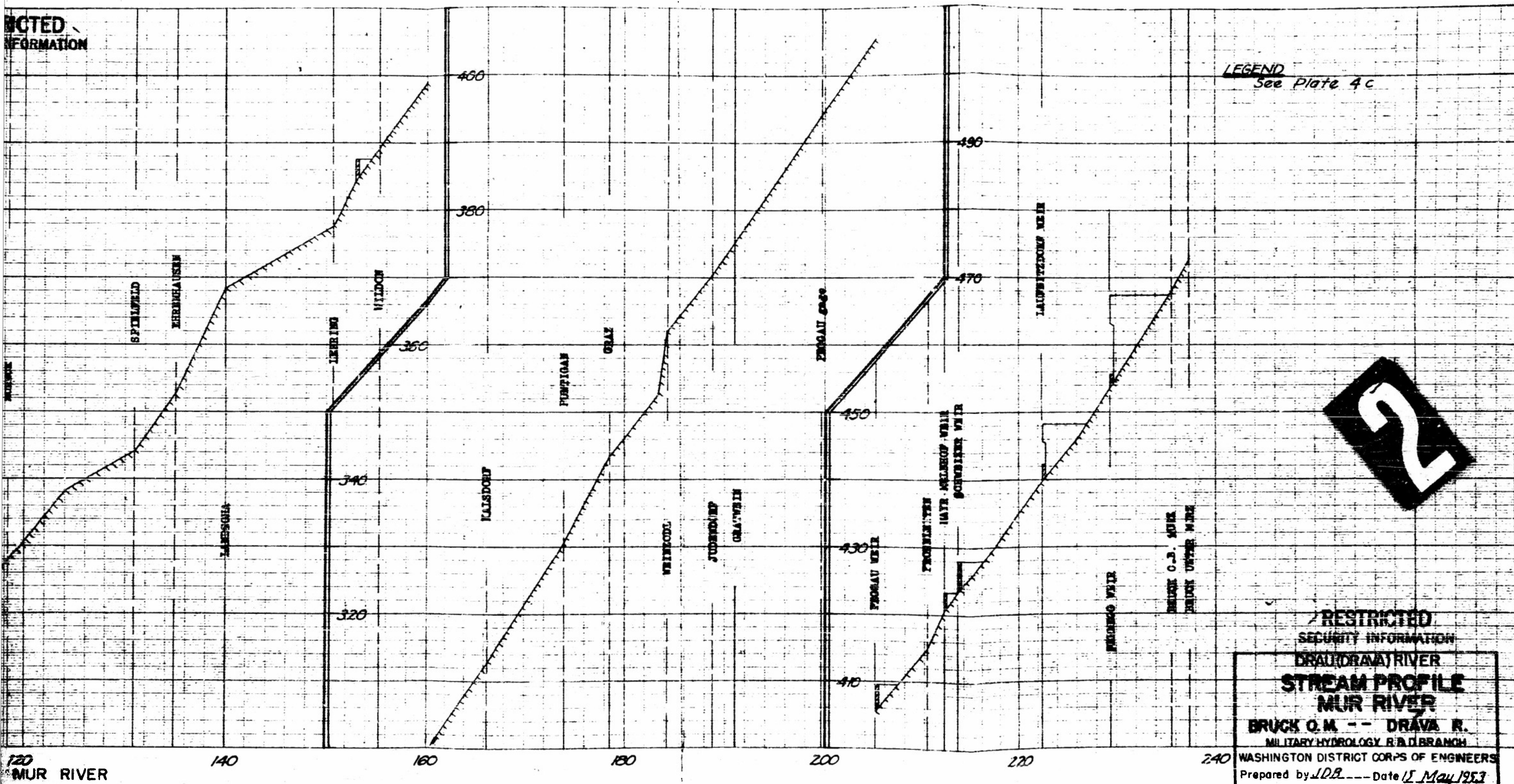
N OF THE MUR RIVER

RESTRICTED
SECURITY INFORMATION

DRAU (DRAVA) RIVER
STREAM PROFILE
MUR RIVER
MUR FALLS - - BRUCK O.M.
MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JDB Date 15 May 1953
Drawn by JJH

PLATE 4 d


RESTRICTED
SECURITY INFORMATION
ELEVATION IN METERS Ü.A.
100
120
140
160
180
200
210
230
250
270
290
0
20
40
60
80
100
120
140
KILOMETERS ABOVE THE MOUTH OF THE MUR RIVER
Confluence w/ Drava River
KOBORIBA
MURSKO SREDISCE
VERZEJ
Austrian-Yugoslav Border
RADKERSBURG
RADKERSBURG
1



RESTRICTED
SECURITY INFORMATION

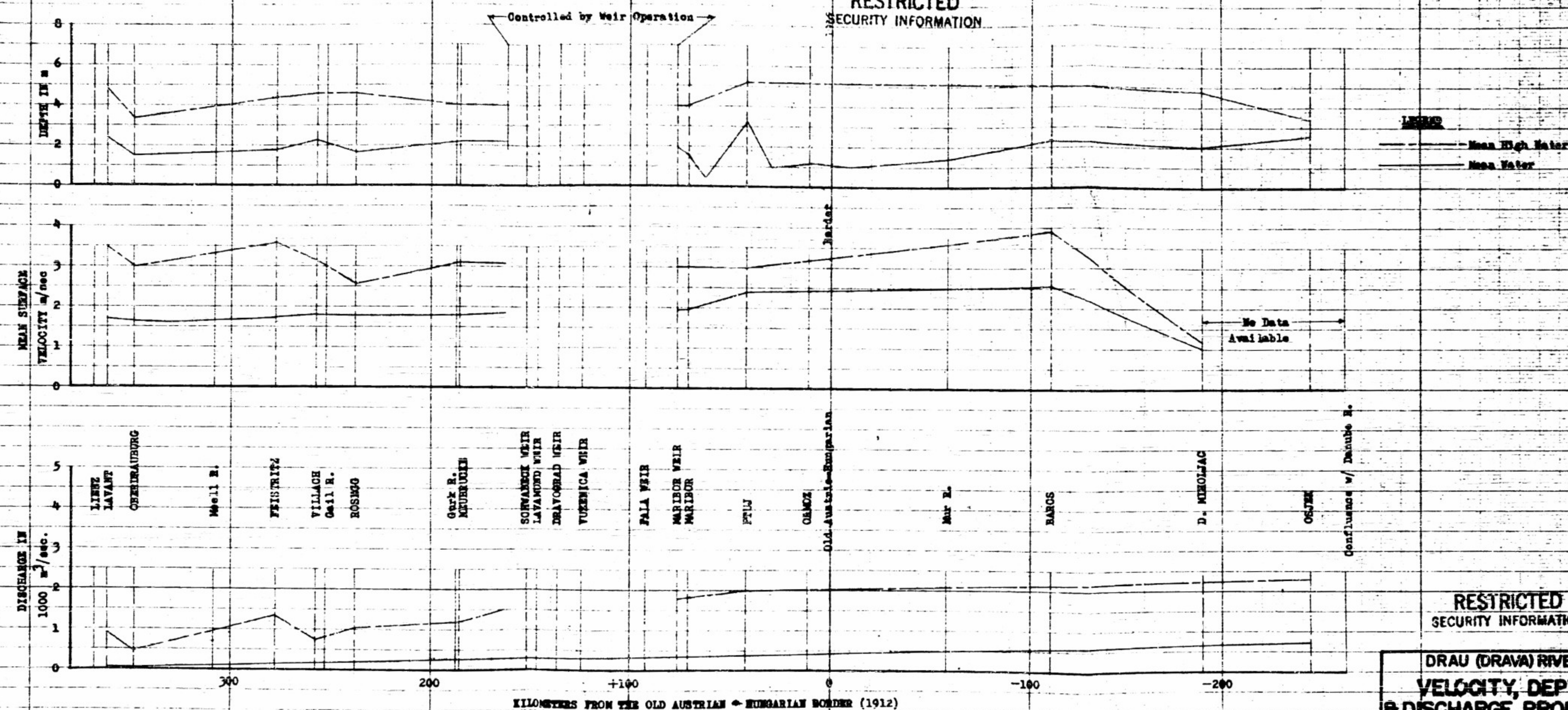
DRAU(DRAVA) RIVER

STREAM PROFILE
MUR RIVER

BRUCK O.M. -- DRAVA R.

MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JDB Date 15 May 1953
Drawn by JJH

PLATE 4e



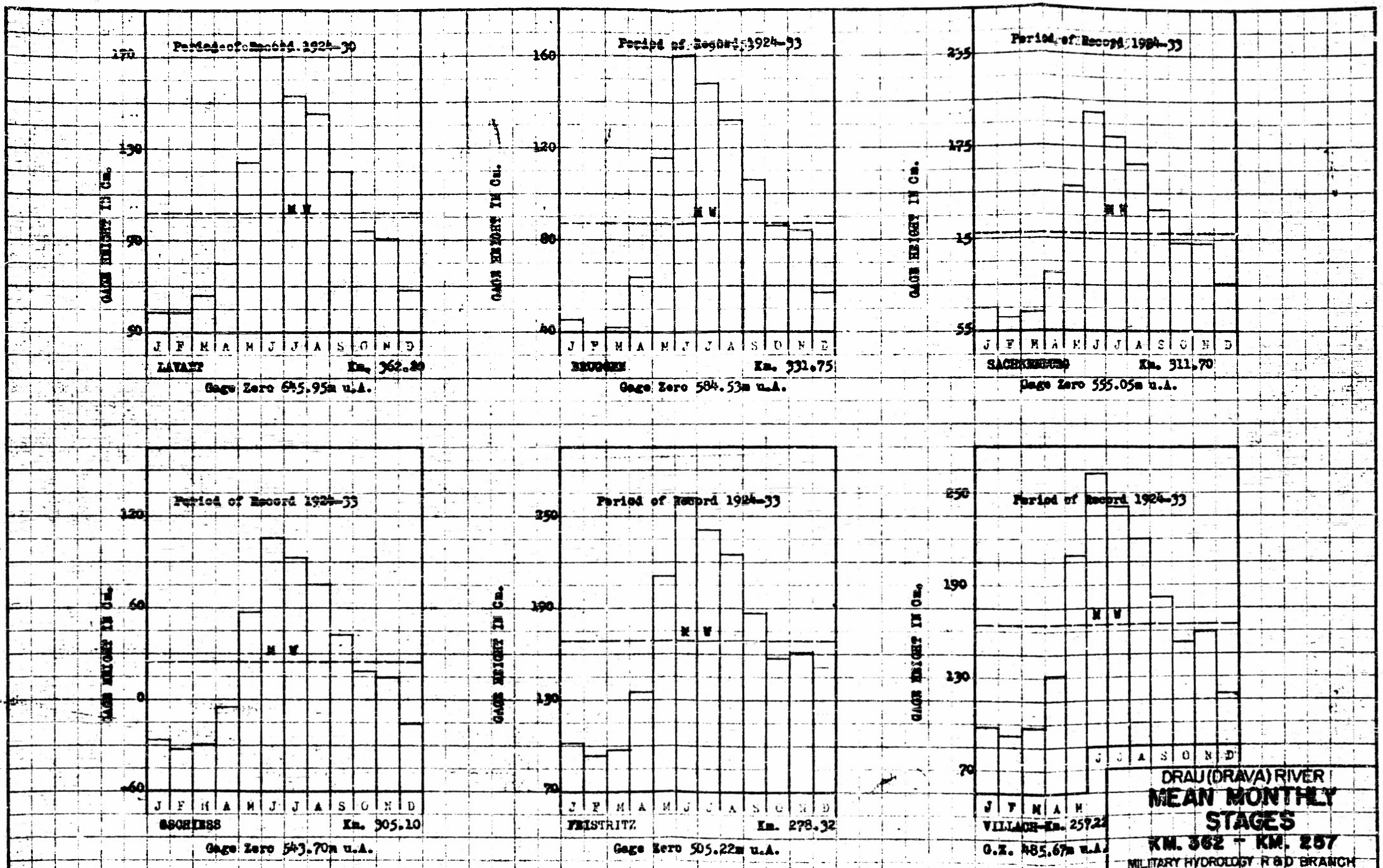
RESTRICTED
SECURITY INFORMATION

DRAU (DRAVA) RIVER

VELOCITY, DEPTH & DISCHARGE PROFILE

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JOB
Drawn by JJH
Date 14 May 1953

PLATE 5



SOURCE: Jahrbuch des Hydrographischen Zentral Bureaus Wien, Austria 1901-1933

DRAU (DRAVA) RIVER

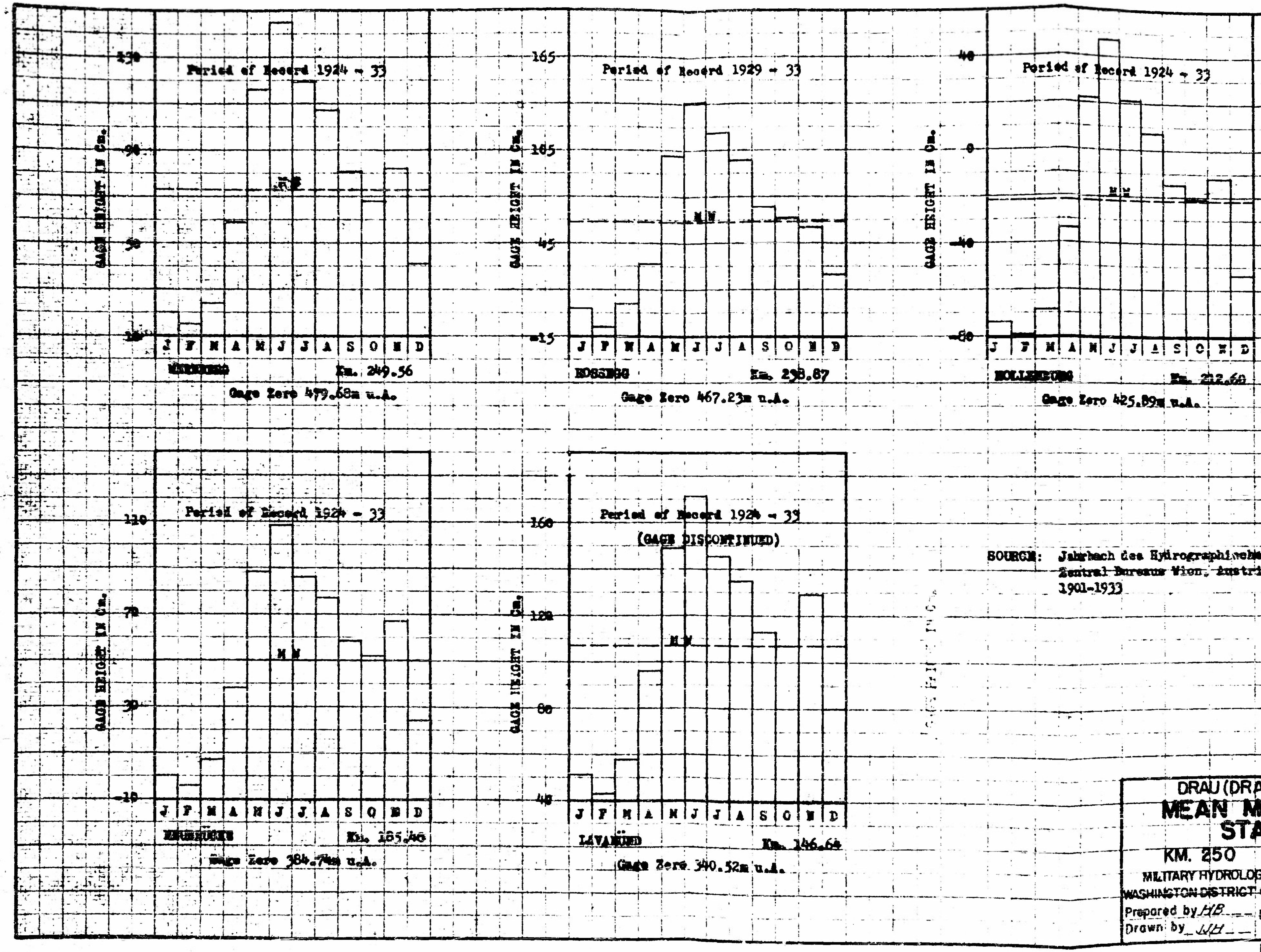
MEAN MONTHLY STAGES

KM. 362 - KM. 257

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by HB Date 5 May 1953
Drawn by JNH

PLATE 68



SOURCE: Jahrbuch des Hydrographischen Zentral Bureaus Wien, Austria 1901-1933

DRAU (DRAVA) RIVER

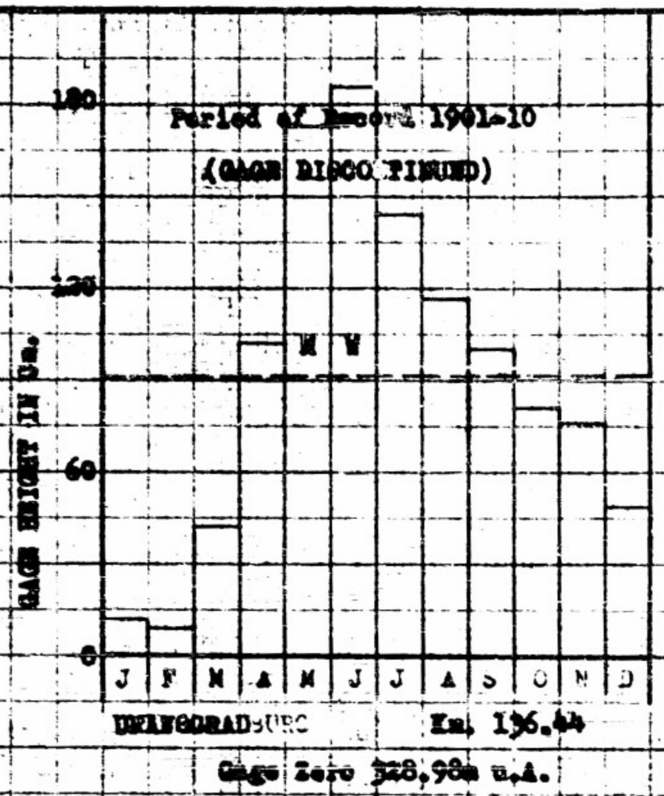
MEAN MONTHLY STAGES

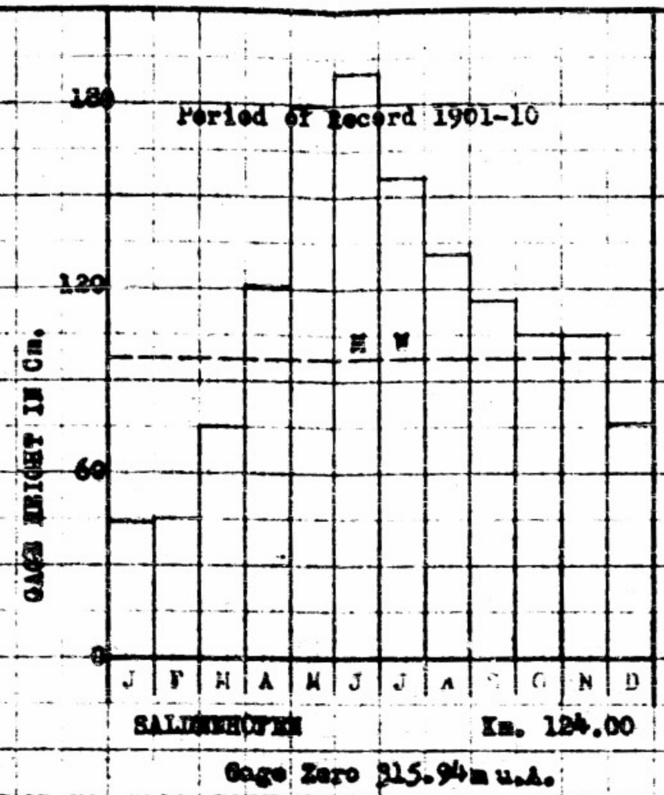
KM. 250 KM. 147

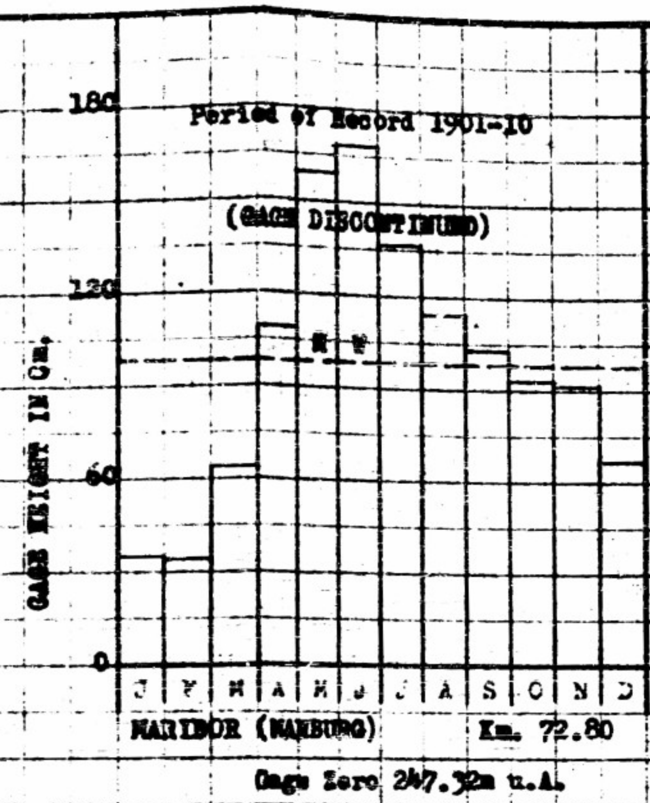
MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

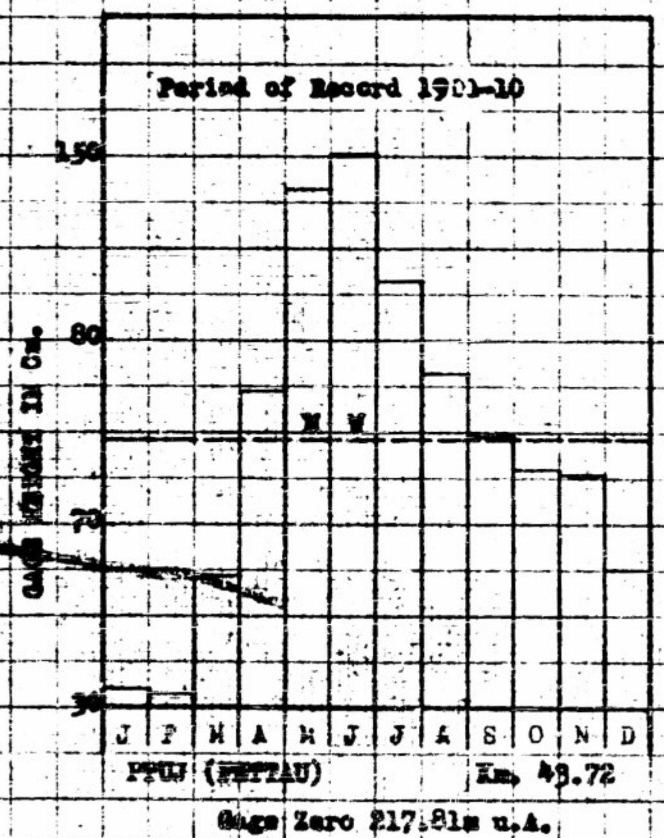
Prepared by HB Date 5 May 1953
Drawn by JJH

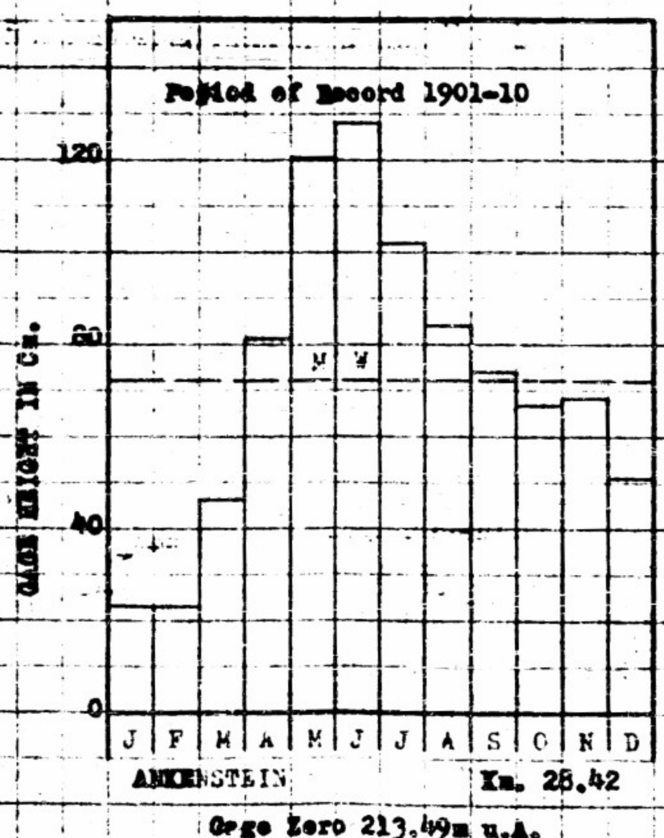
PLATE 6 b









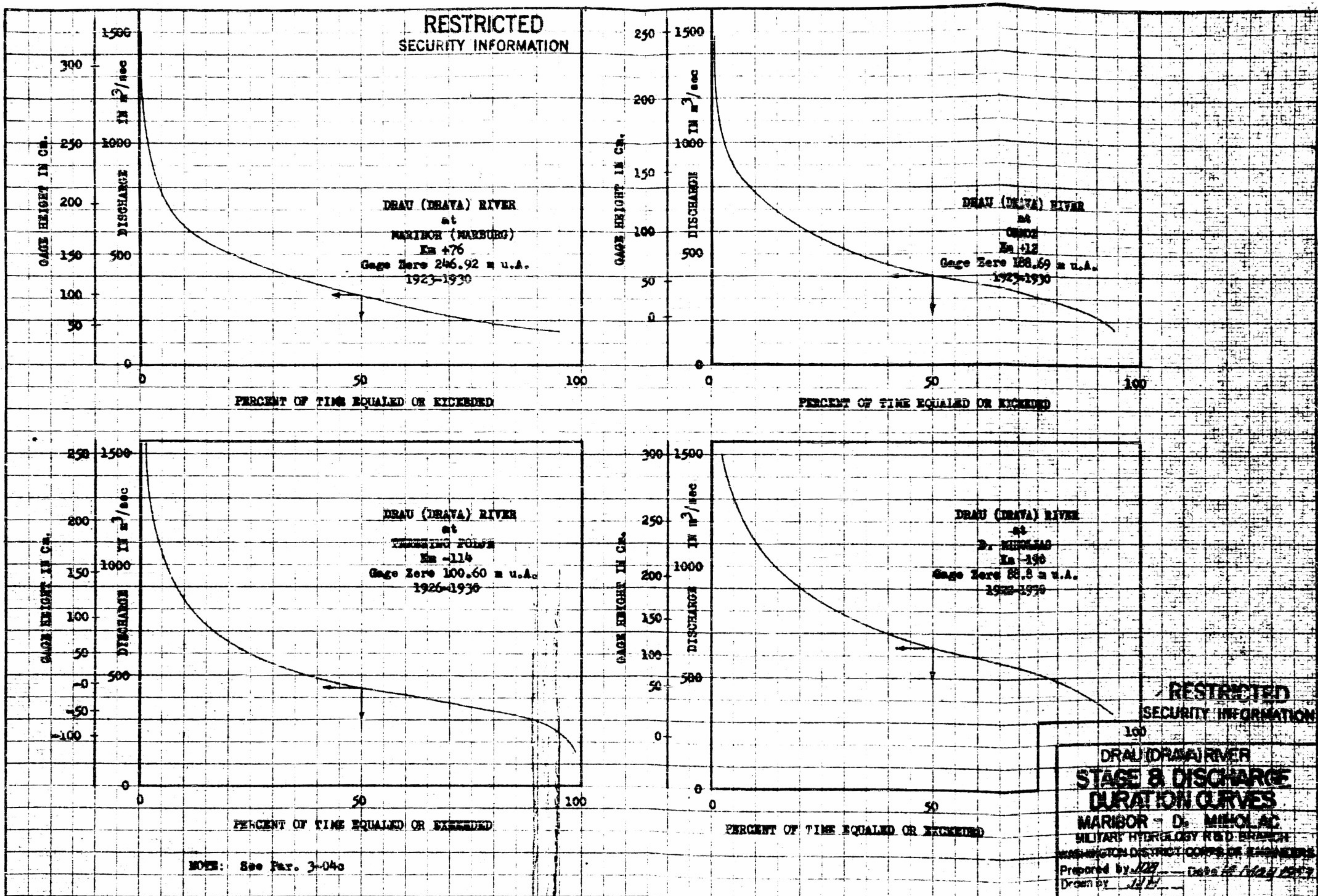


SOURCE: Jahrbuch des Hydrographischen Zentral Bureaus Wien, Austria 1901-1933

DRAU (DRAVA) RIVER
MEAN MONTHLY STAGES
KM. 136 - KM. 28
MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by HB Date 6 May 1953
Drawn by JKK

PLATE 6c

RESTRICTED
SECURITY INFORMATION



NOTE: See Par. 3-04c

RESTRICTED
SECURITY INFORMATION

DRAU (DRAVA) RIVER

STAGE & DISCHARGE DURATION CURVES

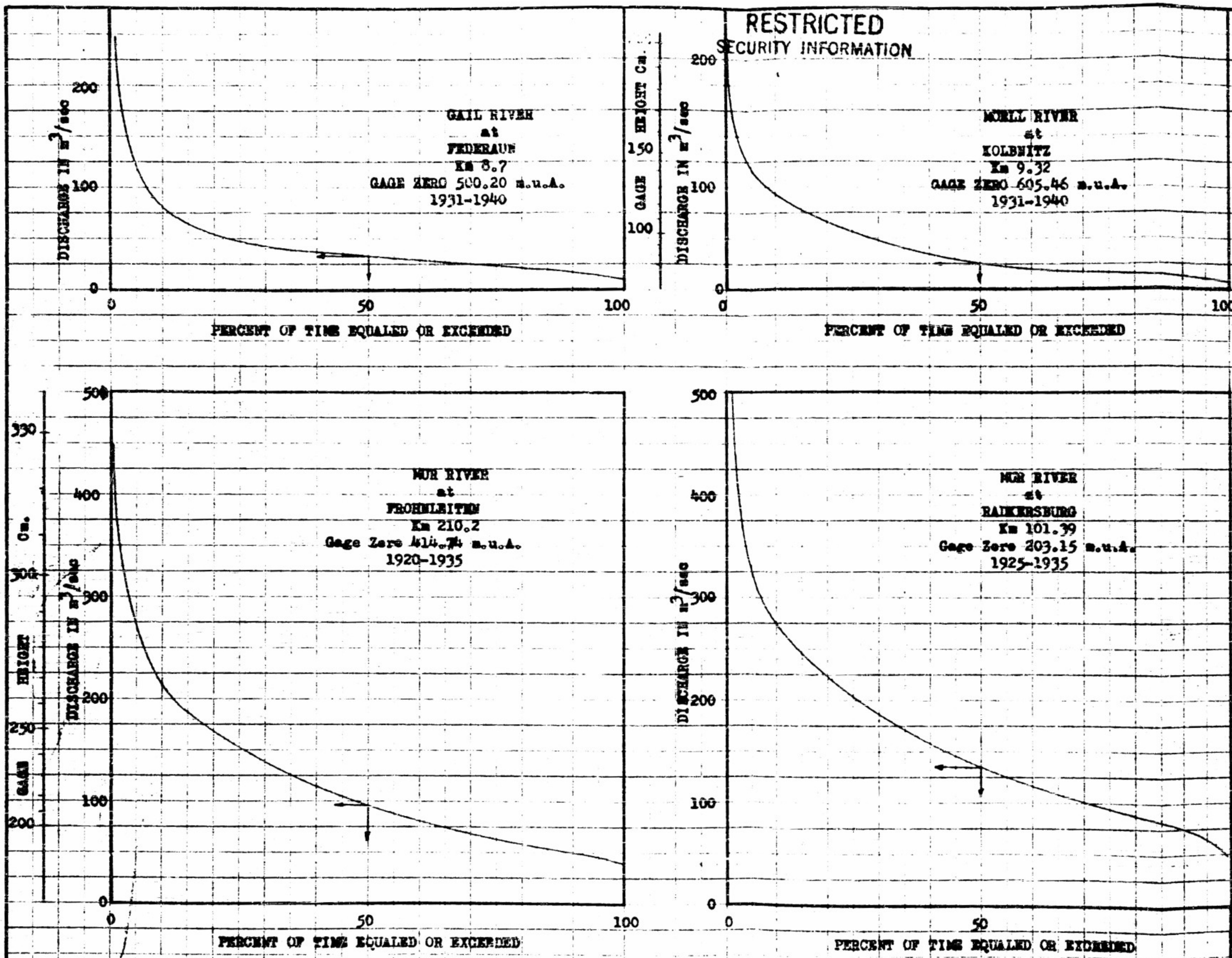
MARIBOR - D. MIHOLJAC

MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by ___ Date ___
Drawn by ___

PLATE 7a

RESTRICTED
SECURITY INFORMATION



NOTE: See Par. 3-04e

RESTRICTED
SECURITY INFORMATION

DRAU (DRAVA) RIVER
STAGE & DISCHARGE DURATION CURVES
FEDERAUN - RADKERSBURG
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT, CORPS OF ENGINEERS
Prepared by JCB Date 13 May 1952
Drawn by JJH

PLATE 7b

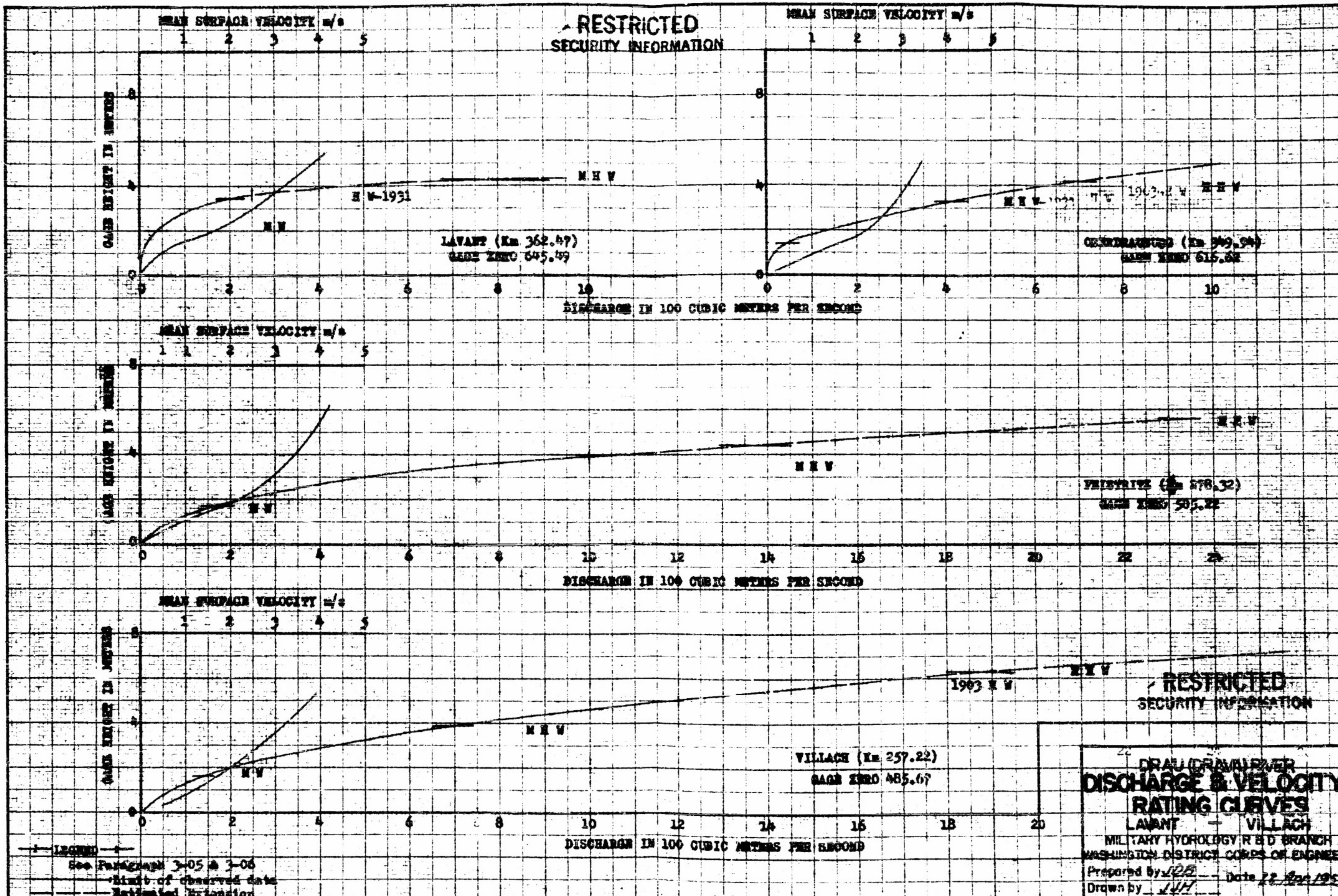

RESTRICTED
SECURITY INFORMATION
MEAN SURFACE VELOCITY m/s
GAGE HEIGHT IN METERS
M H W
H W-1931
M W
LAVANT (Km 362.47)
GAGE ZERO 645.49
1903 H W
GAGE ZERO 616.62
DISCHARGE IN 100 CUBIC METERS PER SECOND
FREISTRITZ (Km 278.32)
GAGE ZERO 505.22
VILLACH (Km 257.22)
GAGE ZERO 485.67
LEGEND
See Paragraph 3-05 & 3-06
Limit of observed data
Estimated Extension
DRAU (DRAVA) RIVER
DISCHARGE & VELOCITY RATING CURVES
LAVANT - VILLACH
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by
Drawn by
Date

PLATE 8a

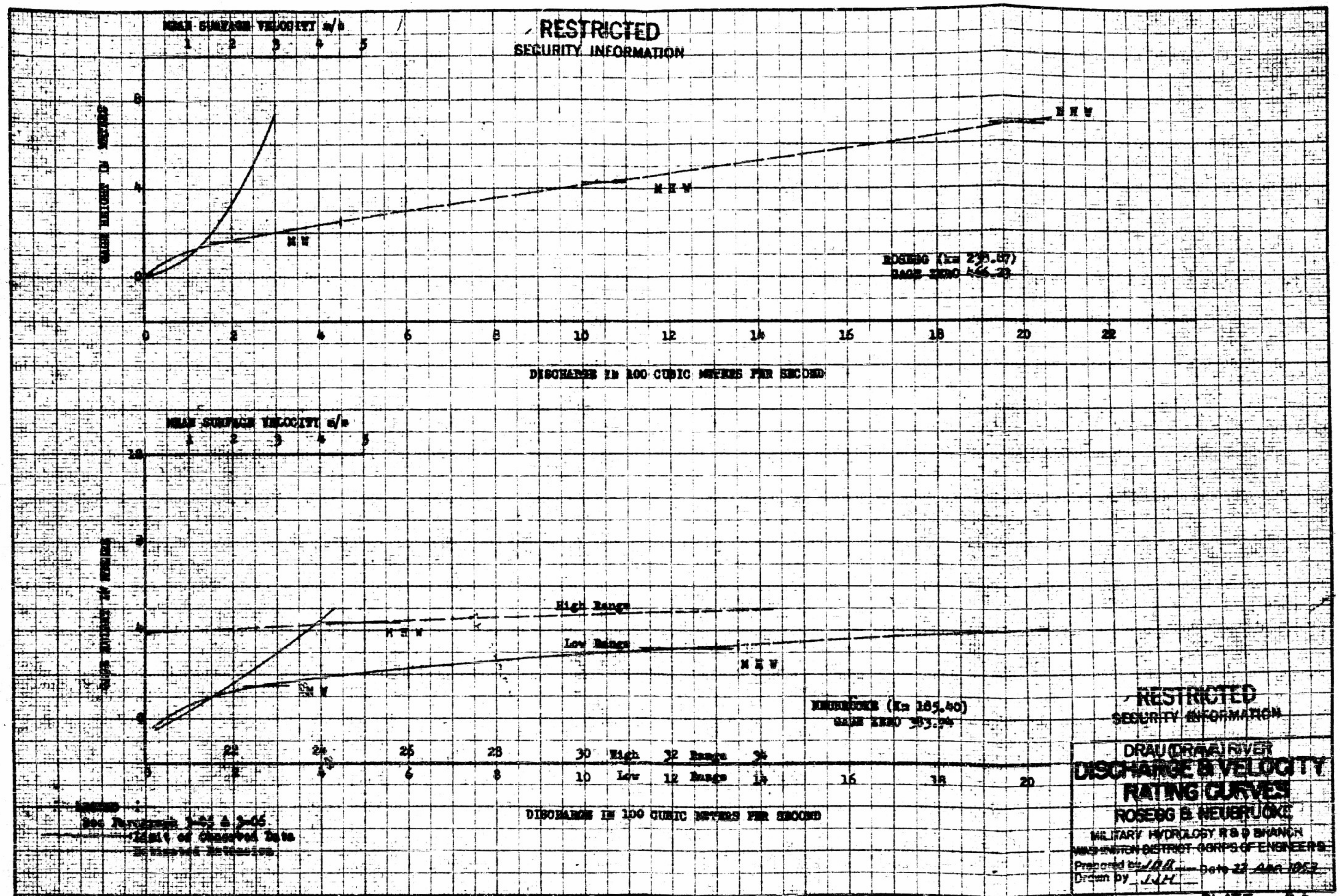
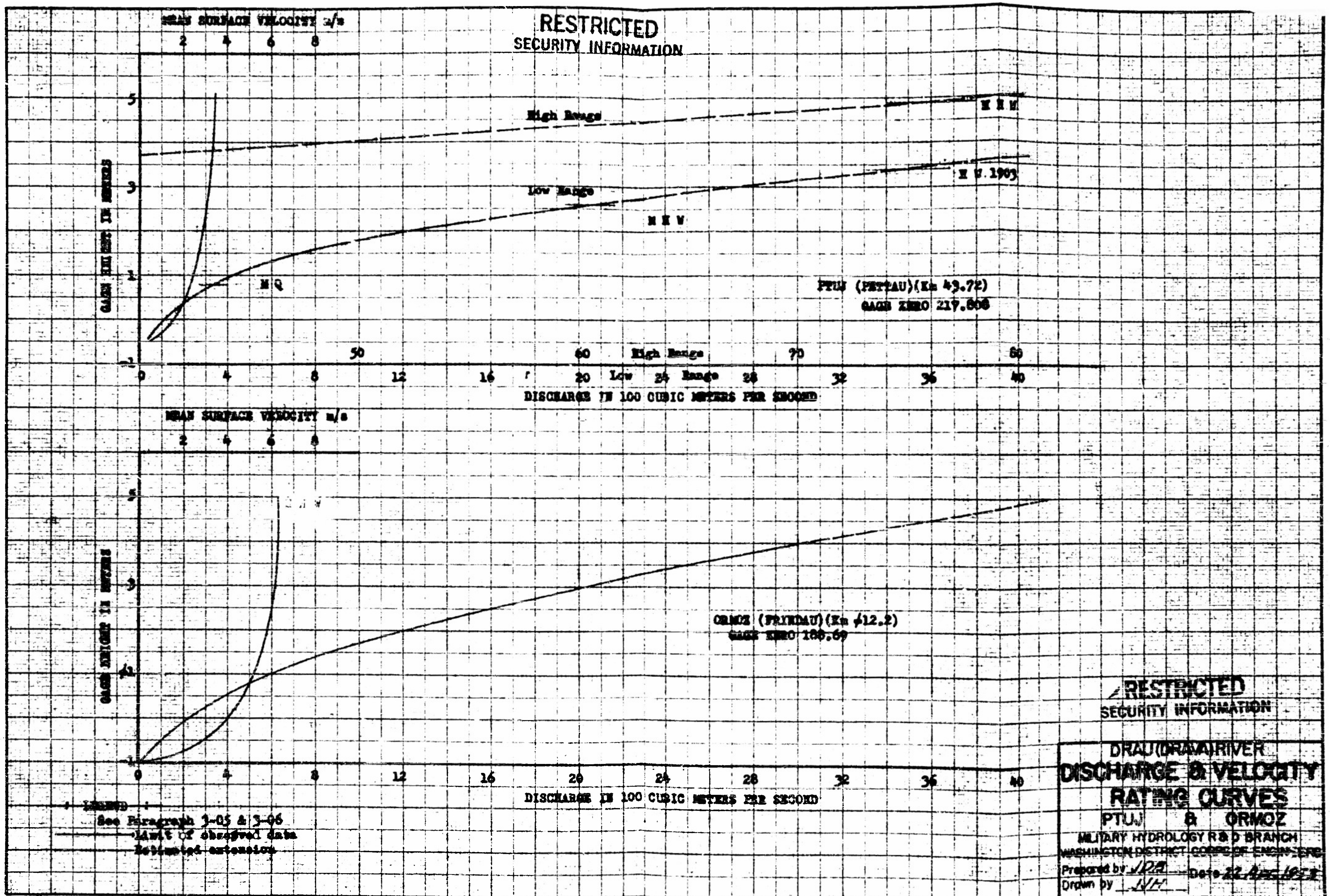

RESTRICTED
SECURITY INFORMATION
MEAN SURFACE VELOCITY m/s
1 2 3 4 5
M H W
M W
0 2 4 6 8 10 12 14 16 18 20 22
DISCHARGE IN 100 CUBIC METERS PER SECOND
MEAN SURFACE VELOCITY m/s
1 2 3 4 5
High Range
Low Range
M H W
M W
22 24 26 28 30 High 32 Range 34
0 2 4 6 8 10 Low 12 Range 14 16 18 20
DISCHARGE IN 100 CUBIC METERS PER SECOND
LEGEND
Limit of Observed Data
Estimated Extension
RESTRICTED
SECURITY INFORMATION
DRAU (DRAVA) RIVER
DISCHARGE & VELOCITY
RATING CURVES
ROSEGG & NEUBRUCKE
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JAB Date 22 Apr 1952
Drawn by JJH

PLATE 8 b

RESTRICTED
SECURITY INFORMATION

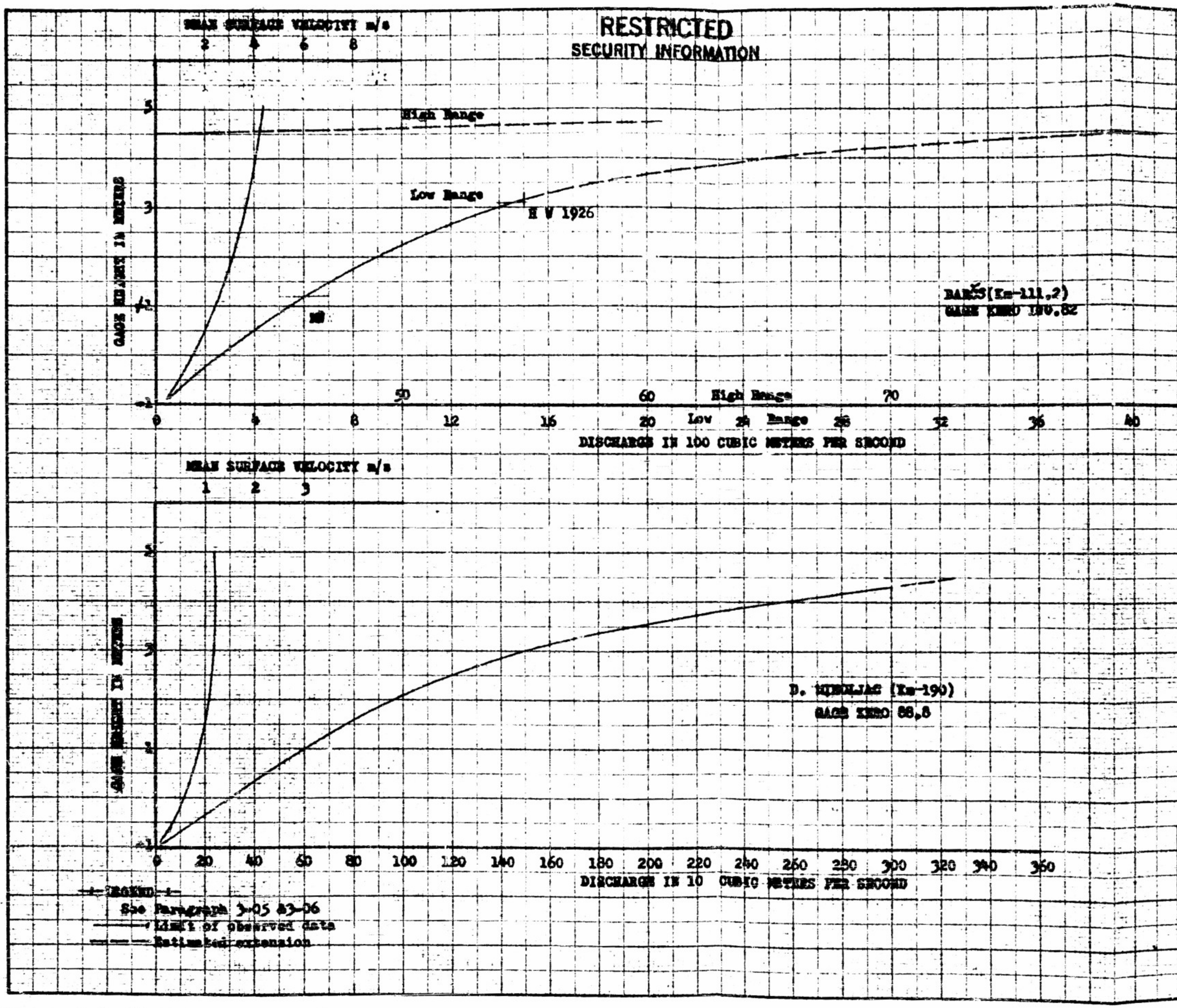


RESTRICTED
SECURITY INFORMATION

DRAU(DRAVA)RIVER
DISCHARGE & VELOCITY
RATING CURVES
PTUJ & ORMOZ
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JDM Date 22 Apr 1952
Drawn by JJH

PLATE 8c

RESTRICTED
SECURITY INFORMATION



RESTRICTED
SECURITY INFORMATION

DRAU (DRAVA) RIVER
DISCHARGE & VELOCITY RATING CURVES
BARCS & D. MIHOLJAC
MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JDB Date 22 Apr 1952
Drawn by LLH

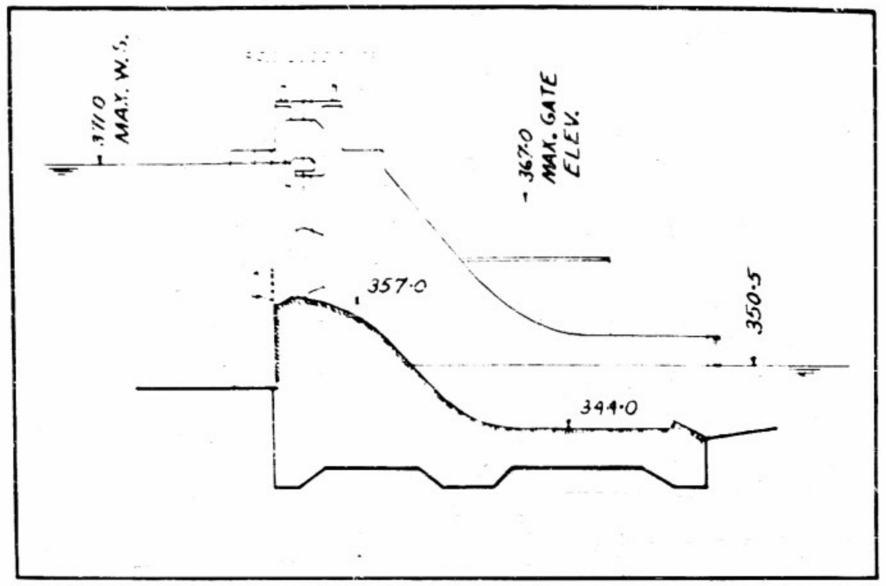
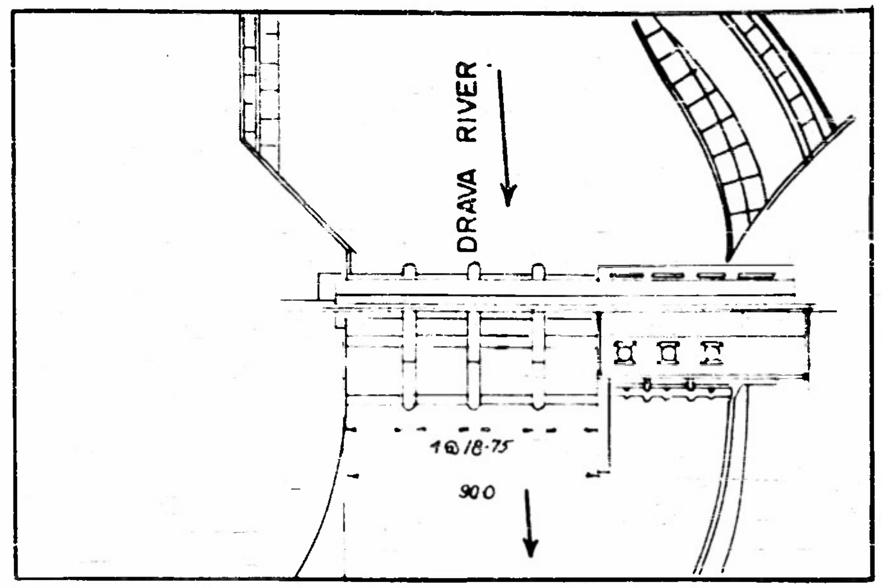
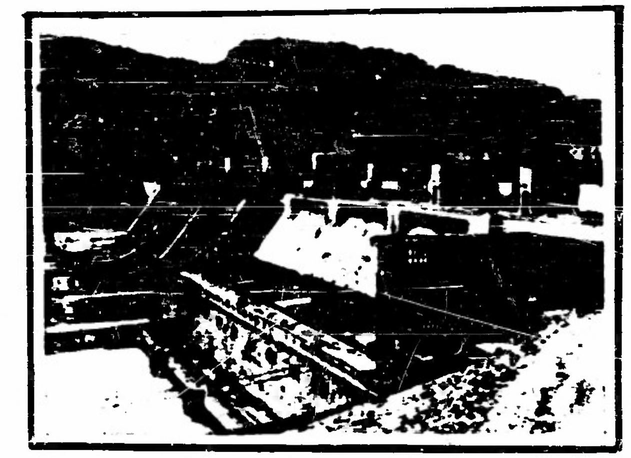


Fig Ia Schwabeck Weir - Drava River - **Serial No. 1**



Ib



Ic

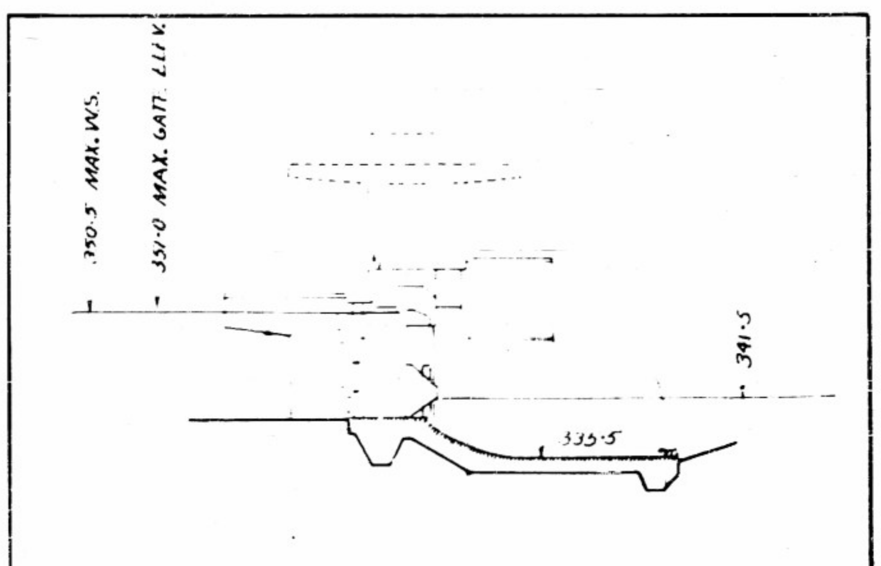
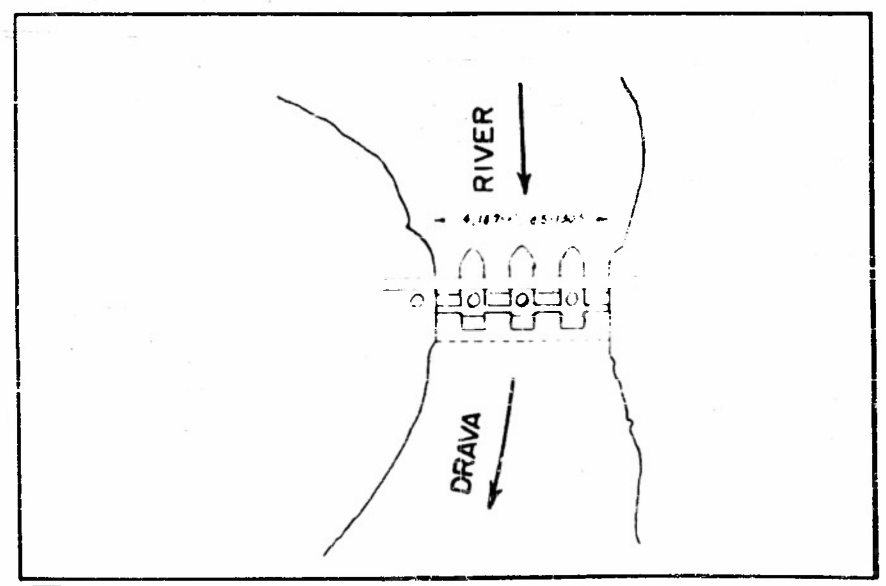


Fig IIa Lavamund Weir - Drava River - **Serial No. 2**



IIb

IIc

SOURCE:

Fig.	Ia	Ib	Ic	IIa	IIb	IIc
Ref No	20	18	18	20	19	19
Page	175	64	62	175	100	101

DRAU (DRAVA) RIVER

SKETCHES OF DAMS

SCHWABECK & LAVAMUND

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by US Date 7 May 1953
Drawn by US

PLATE 9a

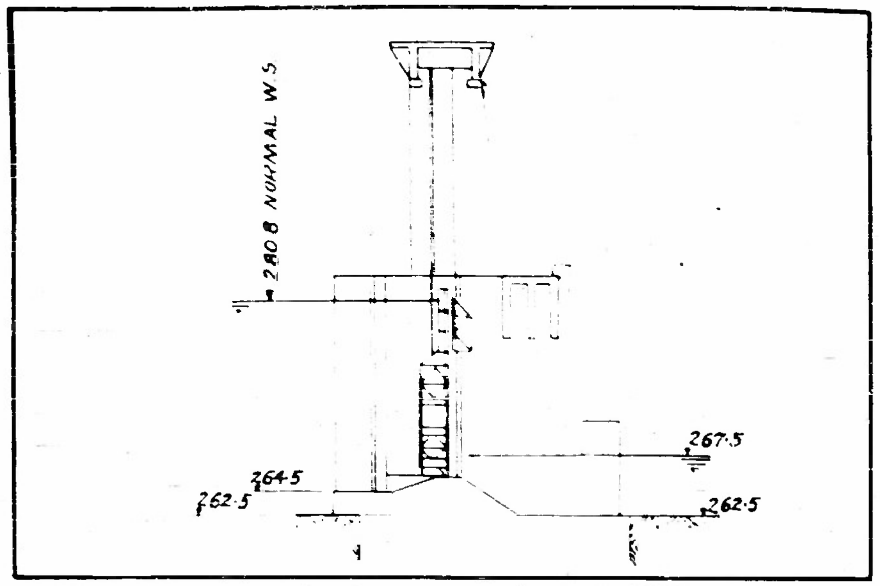
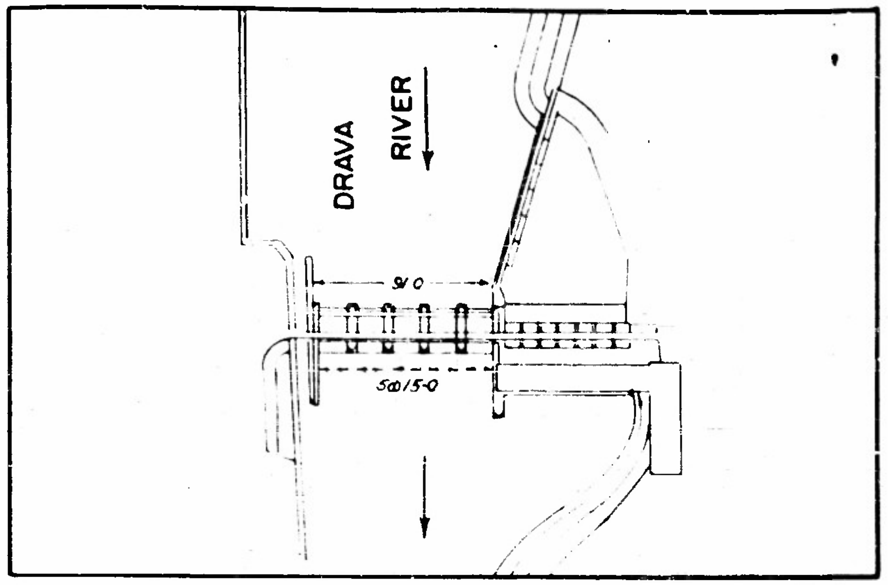
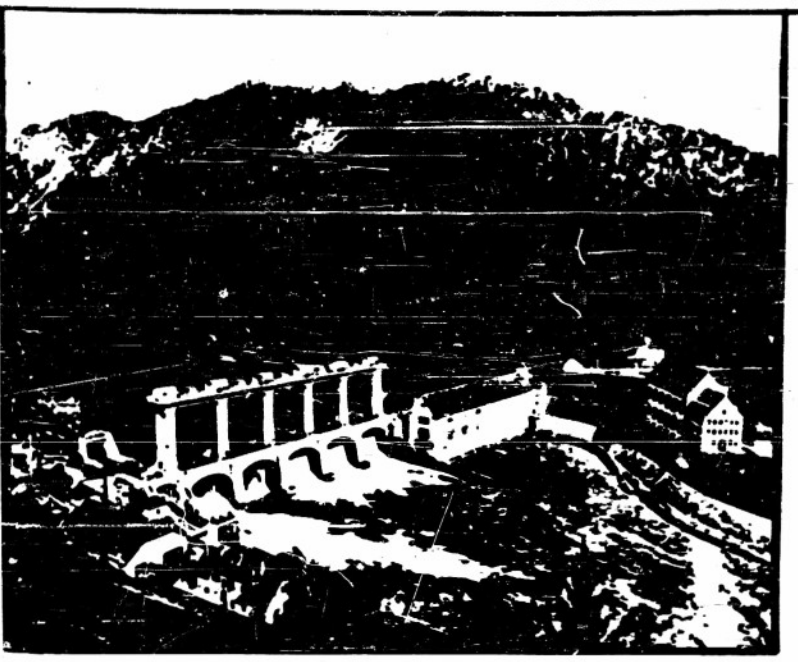


Fig. IIIa Fala (Faal) Weir - Drava River - Serial No. 5



IIIb



IIIc

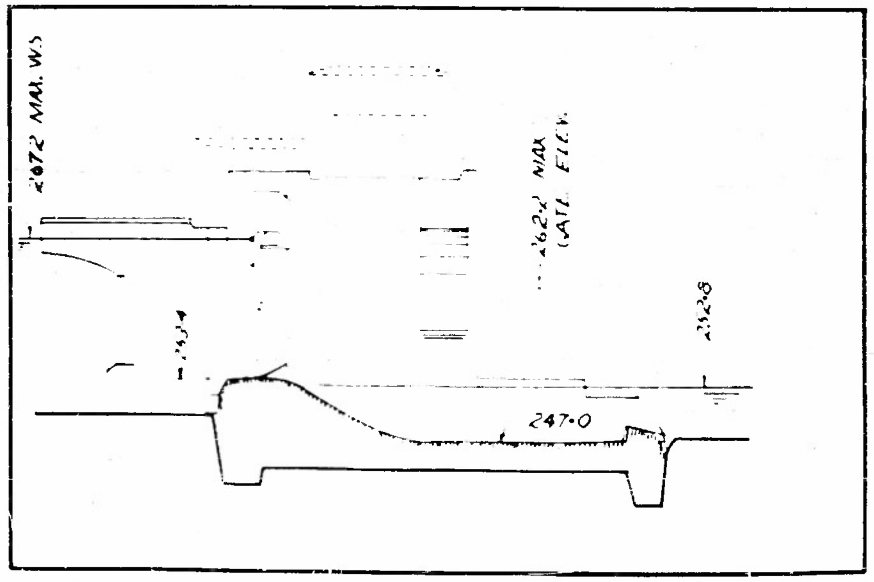
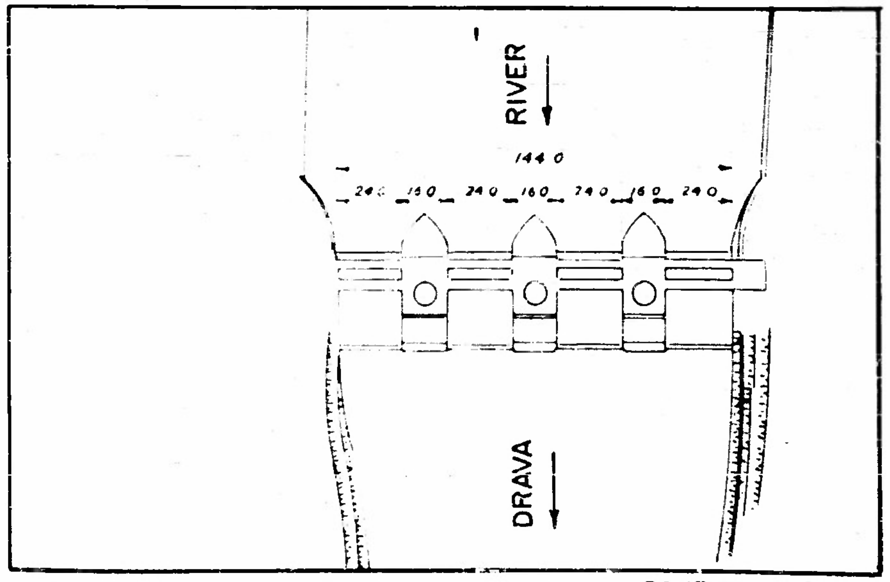
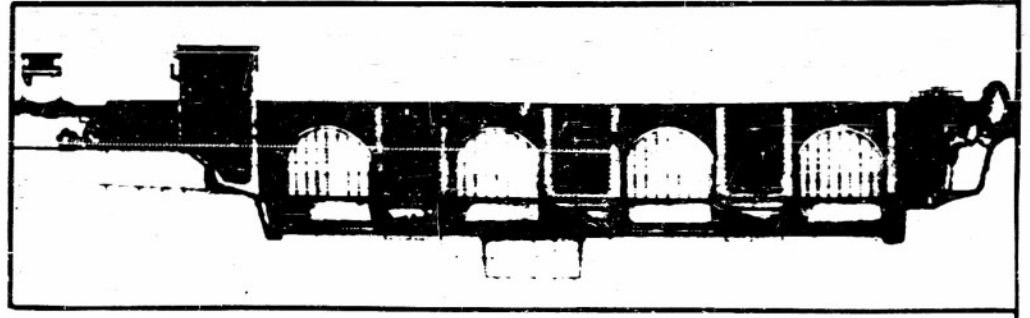


Fig. IVa - Maribor (Marburg) Weir - Drava River - Serial No. 6



IVb



IVc

SOURCE:

Fig.	IIIa	IIIb	IIIc	IVa	IVb	IVc
Ref. No.	27	27	40	20	20	24
Page	623	763	PHOTO 614	175	177	270

DRAU (DRAVA) RIVER

SKETCHES OF DAMS

FALA & MARIBOR

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by YB Date 7 May 1953
Drawn by YB

PLATE 9b

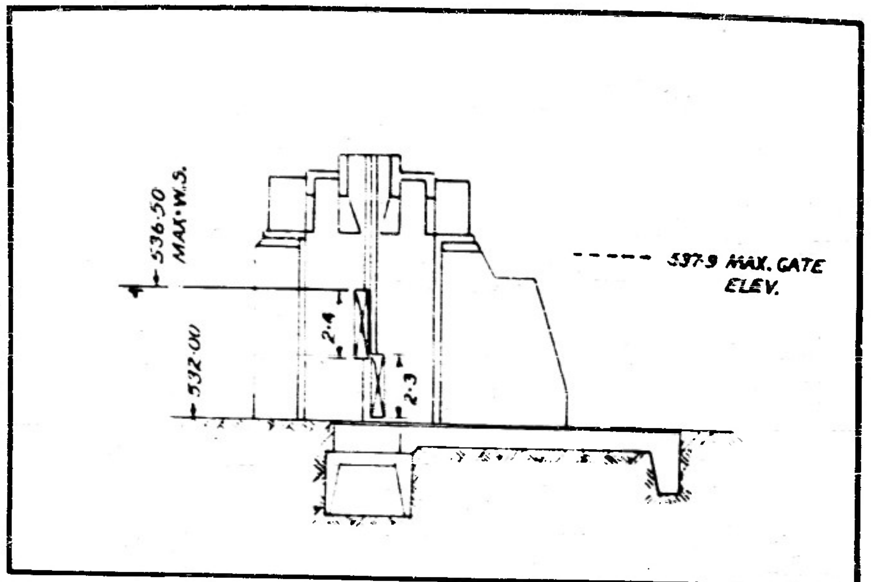
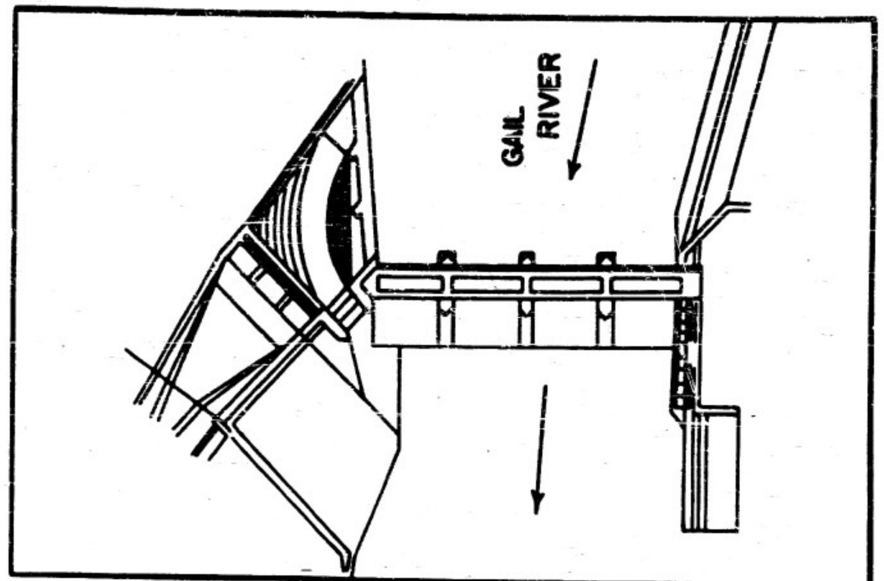


Fig Ⅴa - Arnoldstein Weir - Gail River - Serial No. 15



Ⅴb

PHOTOGRAPH NOT AVAILABLE

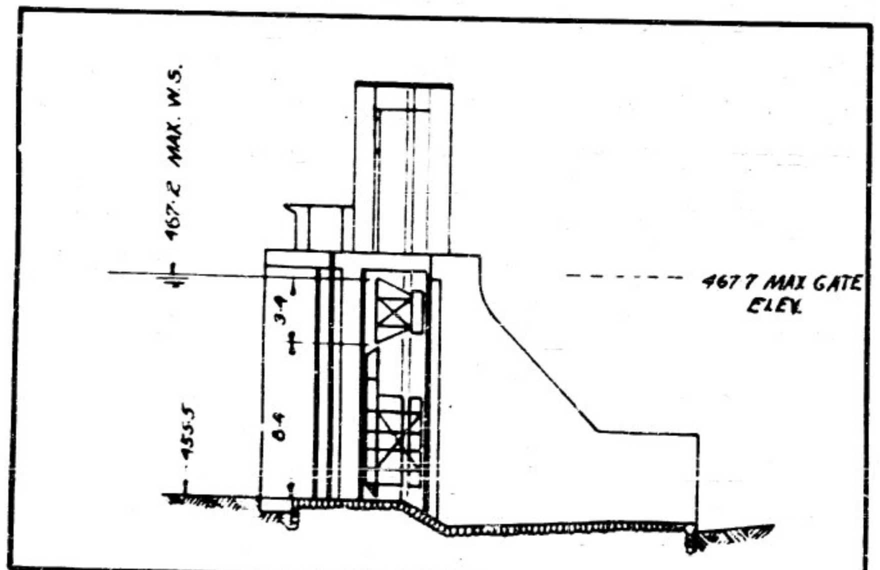
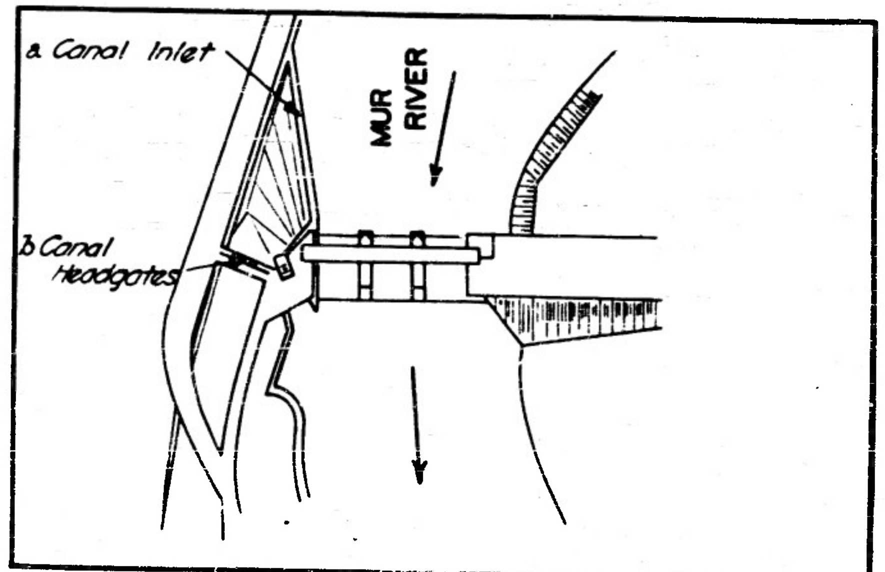


Fig Ⅵa - Pernegg Weir - Mur River - Serial No. 10



Ⅵb

Ⅵc

SOURCE:

Fig.	Ⅴa	Ⅴb	Ⅴc	Ⅵa	Ⅵb	Ⅵc
Ref. No.	27	14		27	27	27
Page	621	[illegible]-7		625	723	723

DRAU (DRAVA) RIVER

SKETCHES OF DAMS

ARNOLDSTEIN & PERNEGG

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by VB Date 14 May 1953
Drawn by VB

PLATE 9c

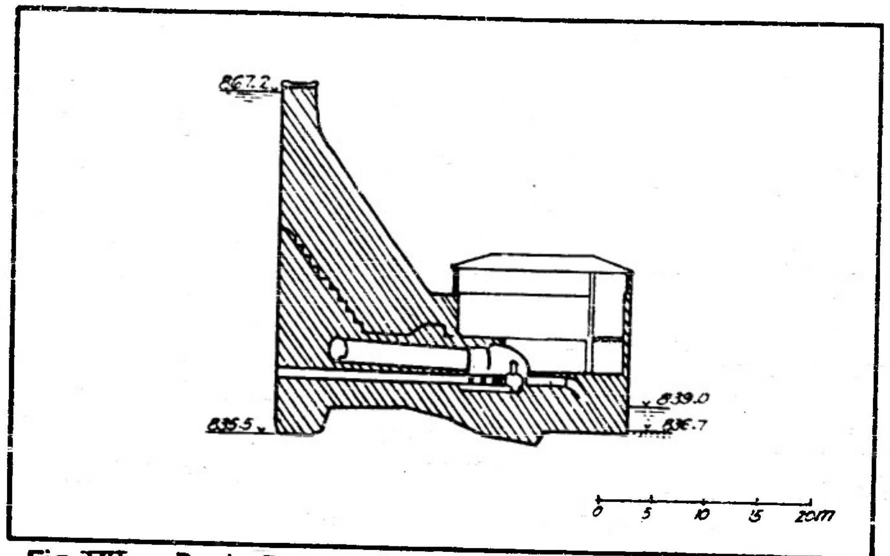
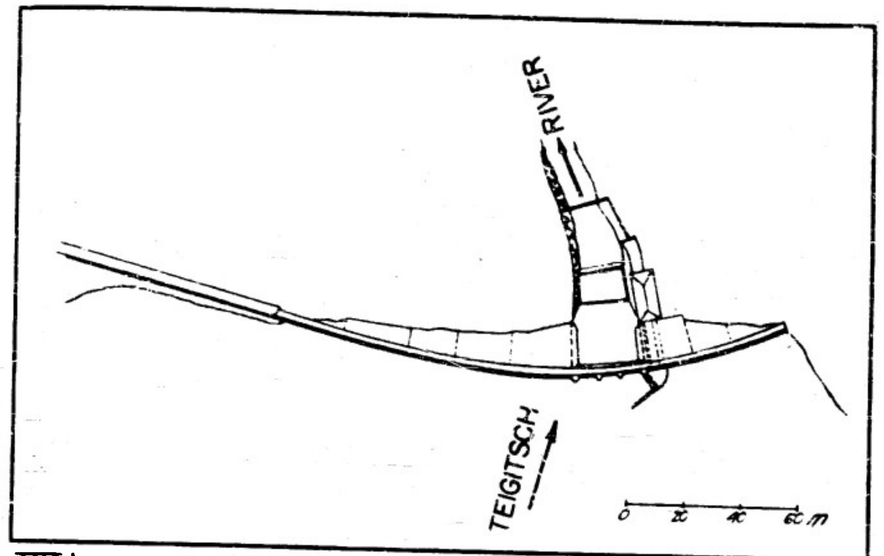
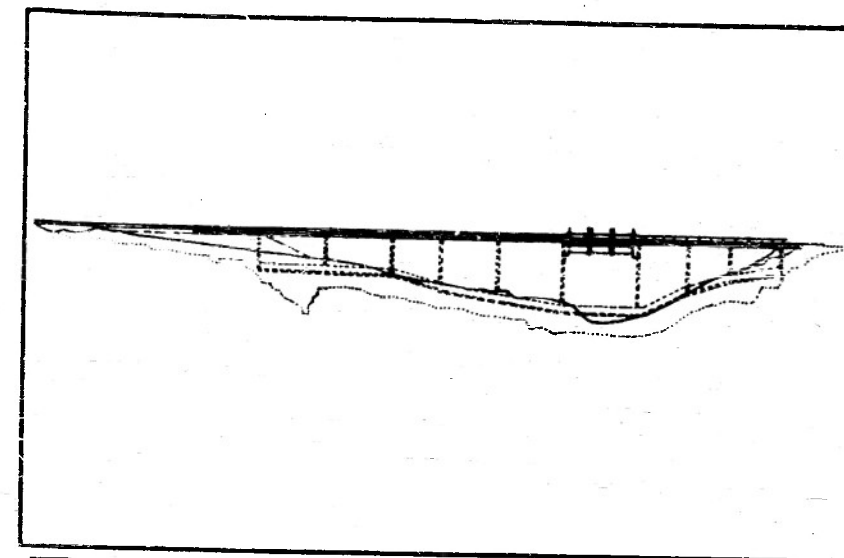


Fig. VIIa Pack Dam - Teigitsch River - Serial No. 7



VII b



VIIc

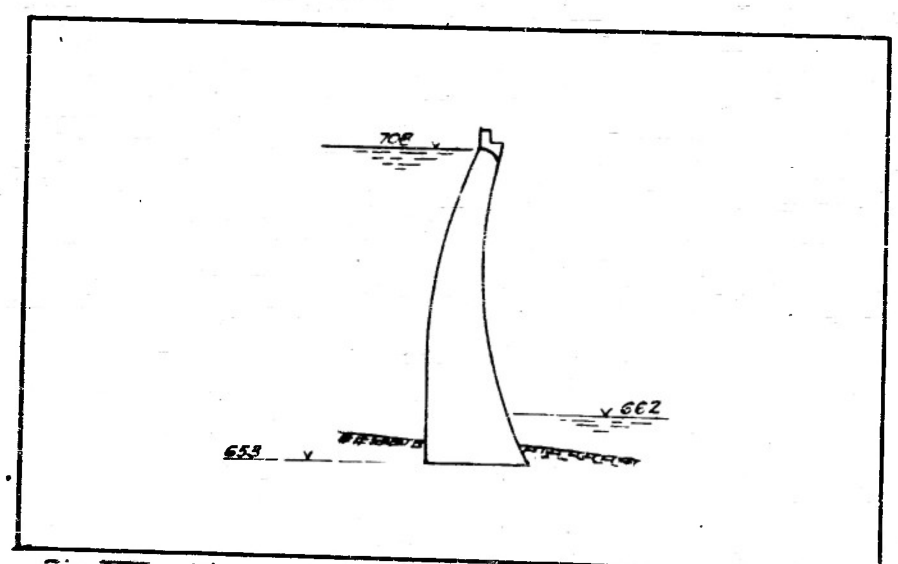
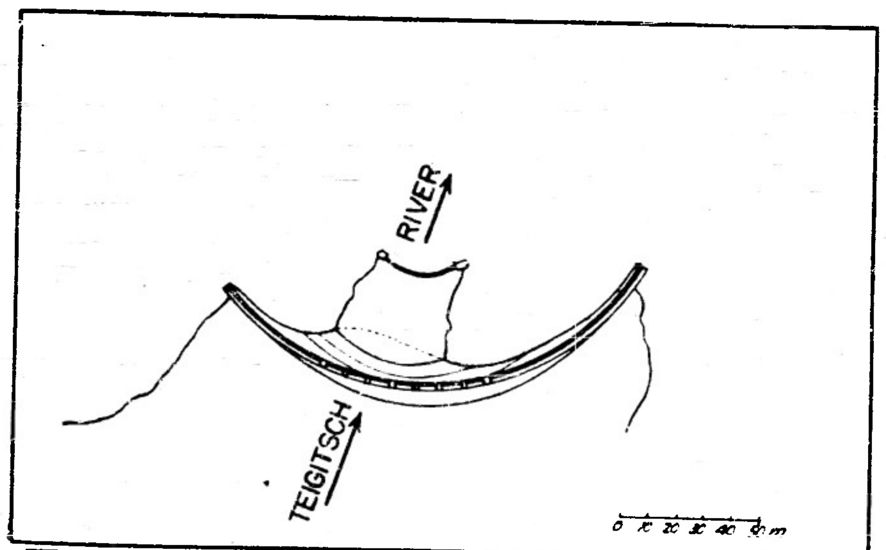
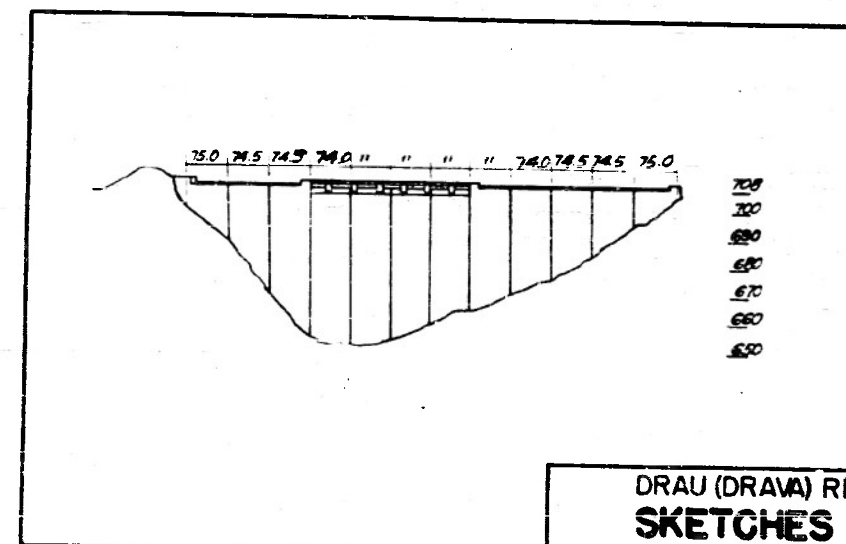


Fig. VIIIa Hiersmann Dam - Teigitsch River - Serial No. 8



VIII b



VIIIc

SOURCE:

Fig.	VIIa	VIIb	VIIc	VIIIa	VIIIb	VIIIc
Ref. No.	37	37	37	38	38	38
Page	3	3	3	186	186	198

DRAU (DRAVA) RIVER

SKETCHES OF DAMS

PACK & HIERSMANN

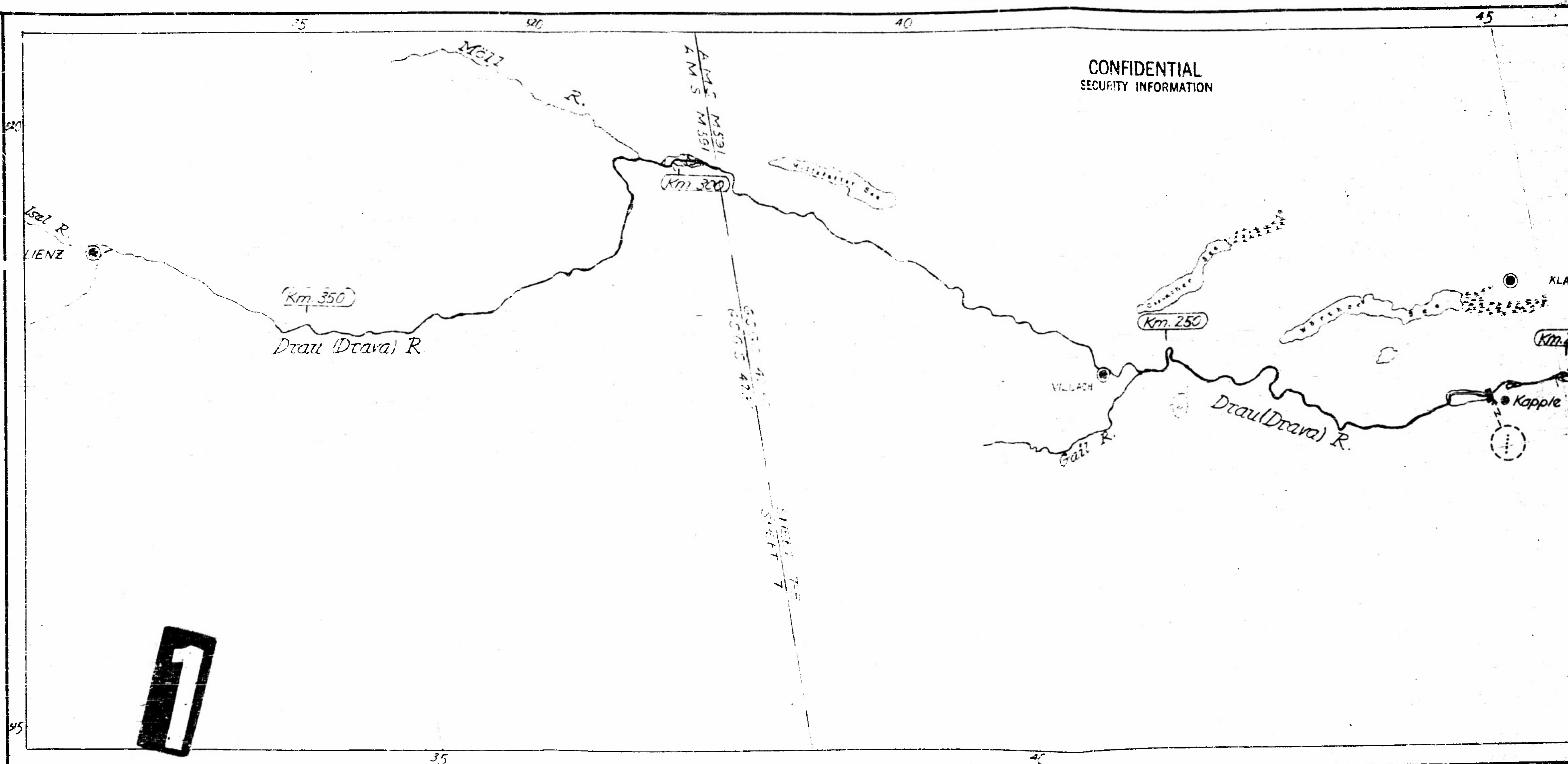
MILITARY HYDROLOGY R & D BRANCH

WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by JJH Date 8 May 1953

Drawn by JJH

PLATE 9 d



CONFIDENTIAL
SECURITY INFORMATION
Möll R.
Isel R.
LIENZ
Km. 350
Drau (Drava) R.
Km. 300
Km. 250
VILLACH
Gail R.
Drau(Drava) R.
Kapple
KLAG
35
40
45
1

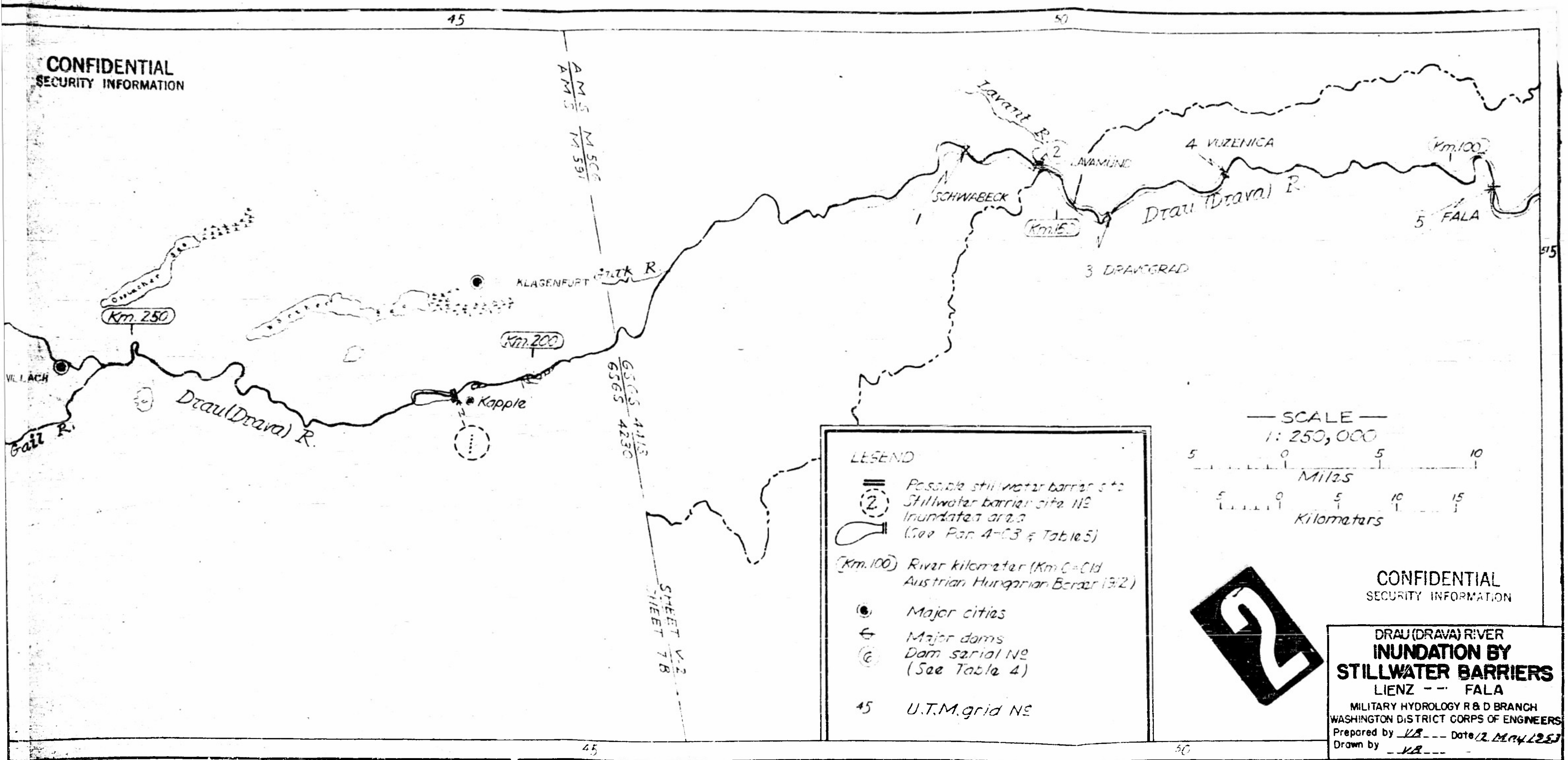
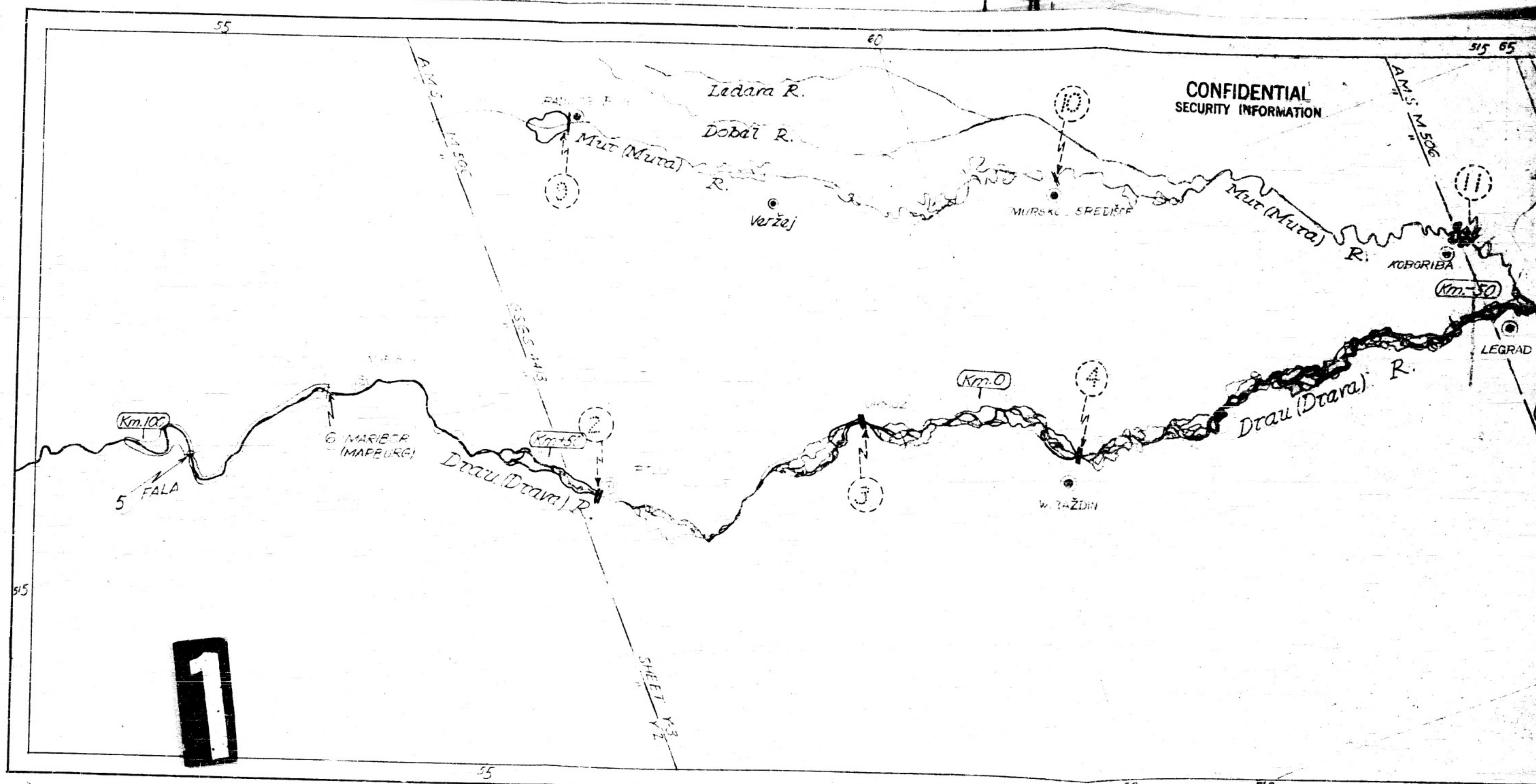
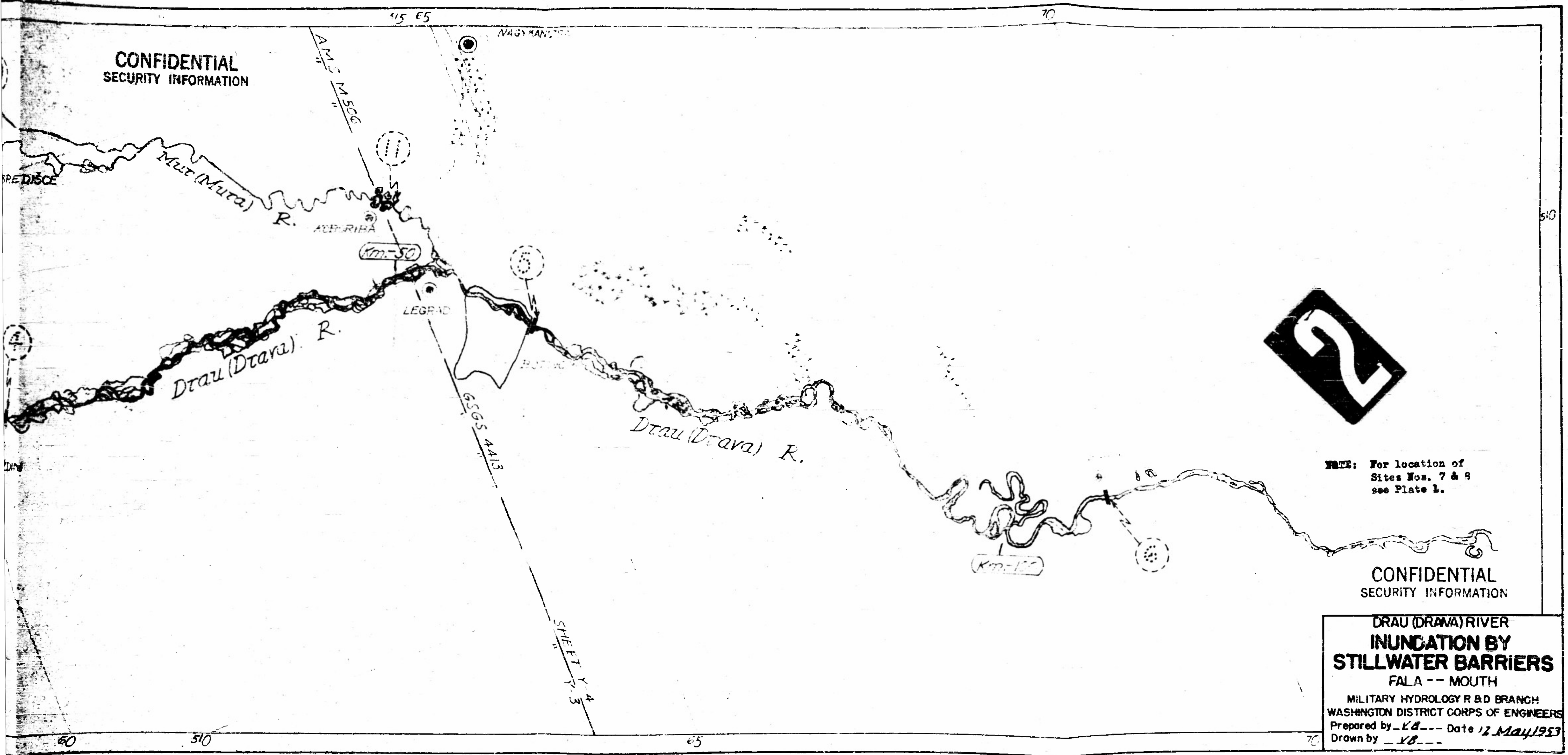

CONFIDENTIAL
SECURITY INFORMATION
45
50
Lavant R.
2
LAVAMÜND
SCHWABECK
Km.150
4 VUZENICA
Km.100
Drau (Drava) R.
5 FALA
3 DRAVOGRAD
KLAGENFURT
Gurk R.
Km. 250
Km.200
VILLACH
Kapple
Drau(Drava) R.
Gail R.
AMS M 506
AMS M 591
GSGS 4415
GSGS 4230
SHEET V2
SHEET 78
SCALE
1: 250,000
Miles
Kilometers
LEGEND
Possible stillwater barrier site
Stillwater barrier site Nº
Inundated area
(See Par. 4-03 & Table 5)
River kilometer (Km 0 = Old Austrian Hungarian Border 1912)
Major cities
Major dams
Dam serial Nº
(See Table 4)
U.T.M. grid Nº
CONFIDENTIAL
SECURITY INFORMATION
2
DRAU (DRAVA) RIVER
INUNDATION BY
STILLWATER BARRIERS
LIENZ -- FALA
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by VB Date 12 May 1953
Drawn by VB

PLATE 10a



CONFIDENTIAL
SECURITY INFORMATION
55
60
515 65
Ledara R.
Dobal R.
Mur (Mura) R.
Veržej
MURSKO SREDIŠĆE
KOBORIBA
Km. -50
LEGRAD
Km. 100
Km. +50
Km. 0
Drau (Drava) R.
FALA
MARIBOR (MARBURG)
VARAŽDIN
A.M.S. M 506
SHEET
515
1
55
60
510



DRAU (DRAVA) RIVER

INUNDATION BY STILLWATER BARRIERS

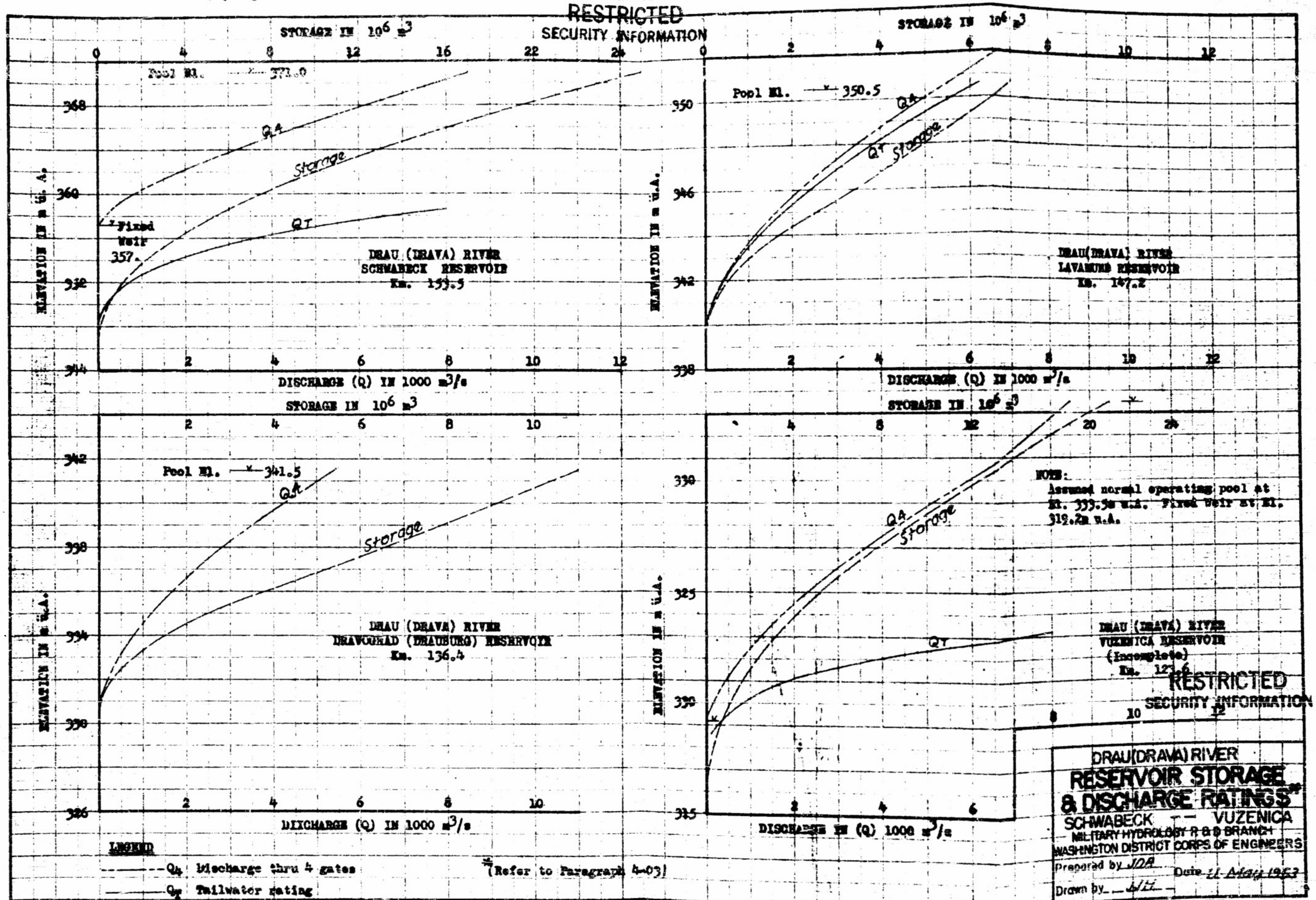
FALA -- MOUTH

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by _VB_ Date 12 May 1953
Drawn by _VB_

PLATE 10 b

RESTRICTED
SECURITY INFORMATION



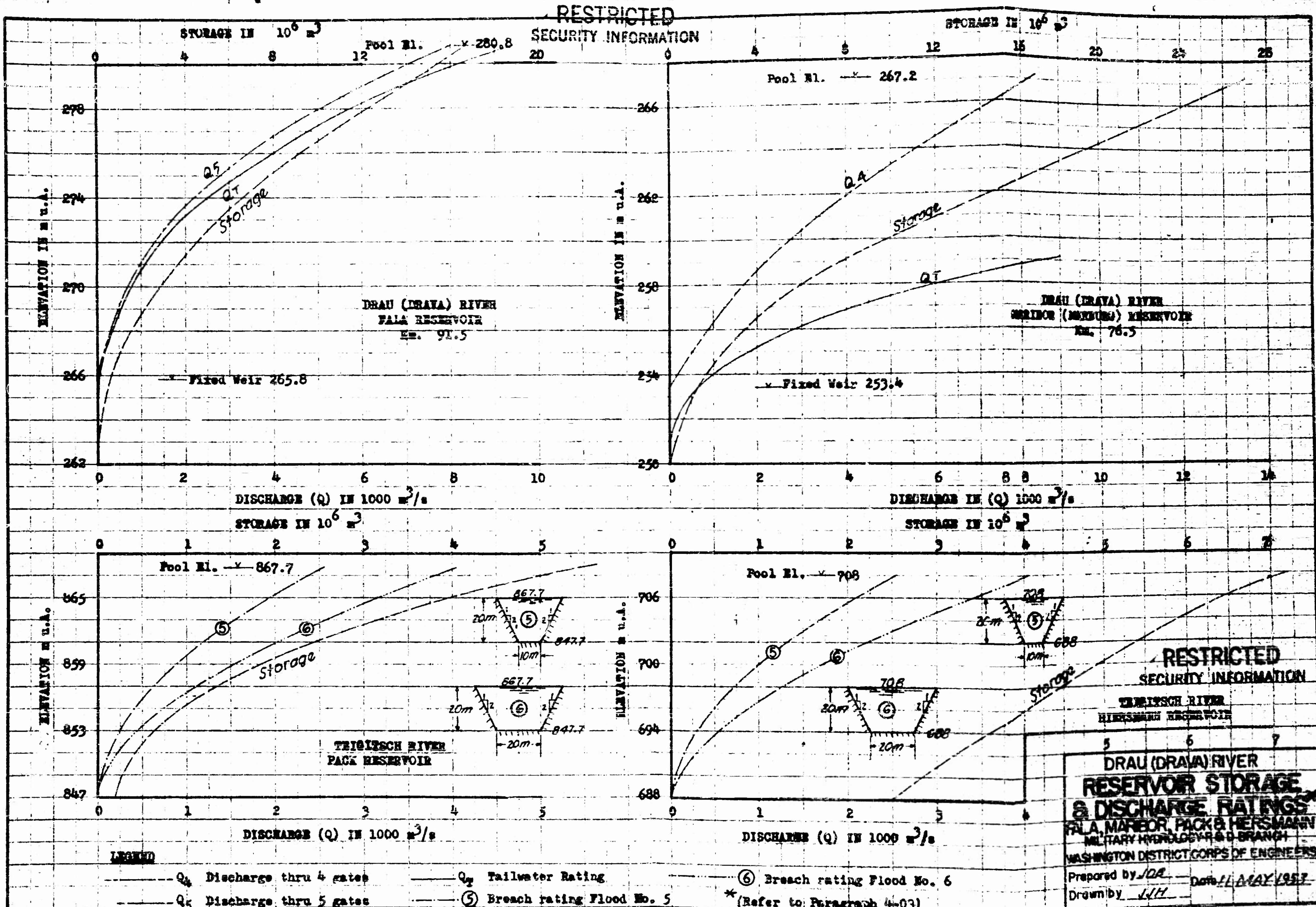

RESTRICTED
SECURITY INFORMATION
STORAGE IN 10^6 m^3
Pool El. 280.8
Q5
QT
Storage
DRAU (DRAVA) RIVER
FALA RESERVOIR
Km. 91.5
Fixed Weir 265.8
ELEVATION IN m u.A.
DISCHARGE (Q) IN 1000 m^3/s
STORAGE IN 10^6 m^3
Pool El. 267.2
Q4
Storage
QT
DRAU (DRAVA) RIVER
MARIBOR (MARBURG) RESERVOIR
Km. 76.5
Fixed Weir 253.4
DISCHARGE IN (Q) 1000 m^3/s
STORAGE IN 10^6 m^3
Pool El. 867.7
Storage
TRIGITSCH RIVER
PACK RESERVOIR
DISCHARGE (Q) IN 1000 m^3/s
STORAGE IN 10^6 m^3
Pool El. 708
Storage
RESTRICTED
SECURITY INFORMATION
TRIGITSCH RIVER
HIERSMANN RESERVOIR
DISCHARGE (Q) IN 1000 m^3/s
LEGEND
Q_4 Discharge thru 4 gates
Q_5 Discharge thru 5 gates
Q_T Tailwater Rating
5 Breach rating Flood No. 5
6 Breach rating Flood No. 6
* (Refer to Paragraph 4-03)
DRAU (DRAVA) RIVER
RESERVOIR STORAGE & DISCHARGE RATINGS
FALA, MARIBOR, PACK & HERSMANN
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JOA Date 11 MAY 1952
Drawn by JJH

PLATE 11b

CONFIDENTIAL
SECURITY INFORMATION

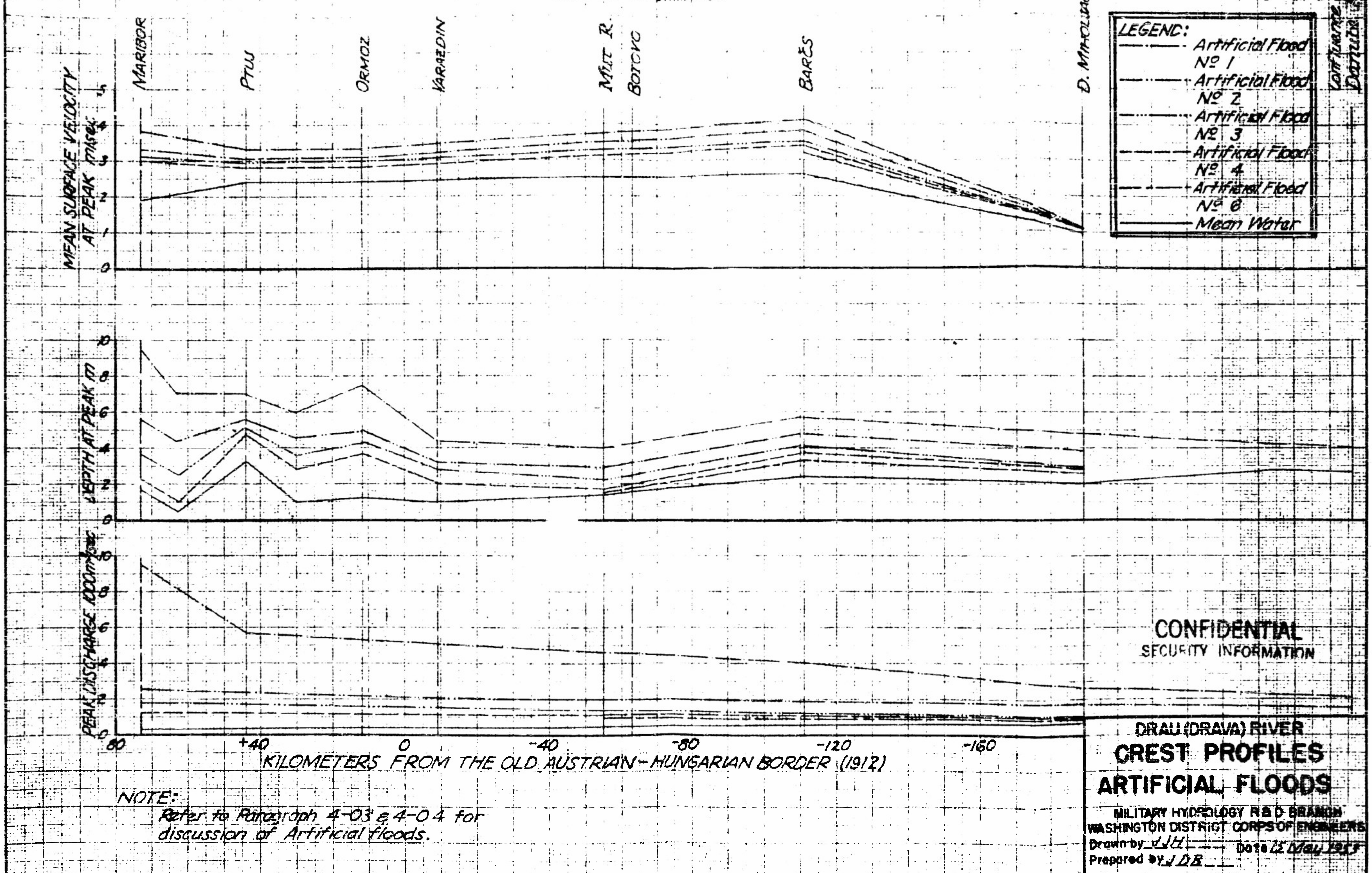
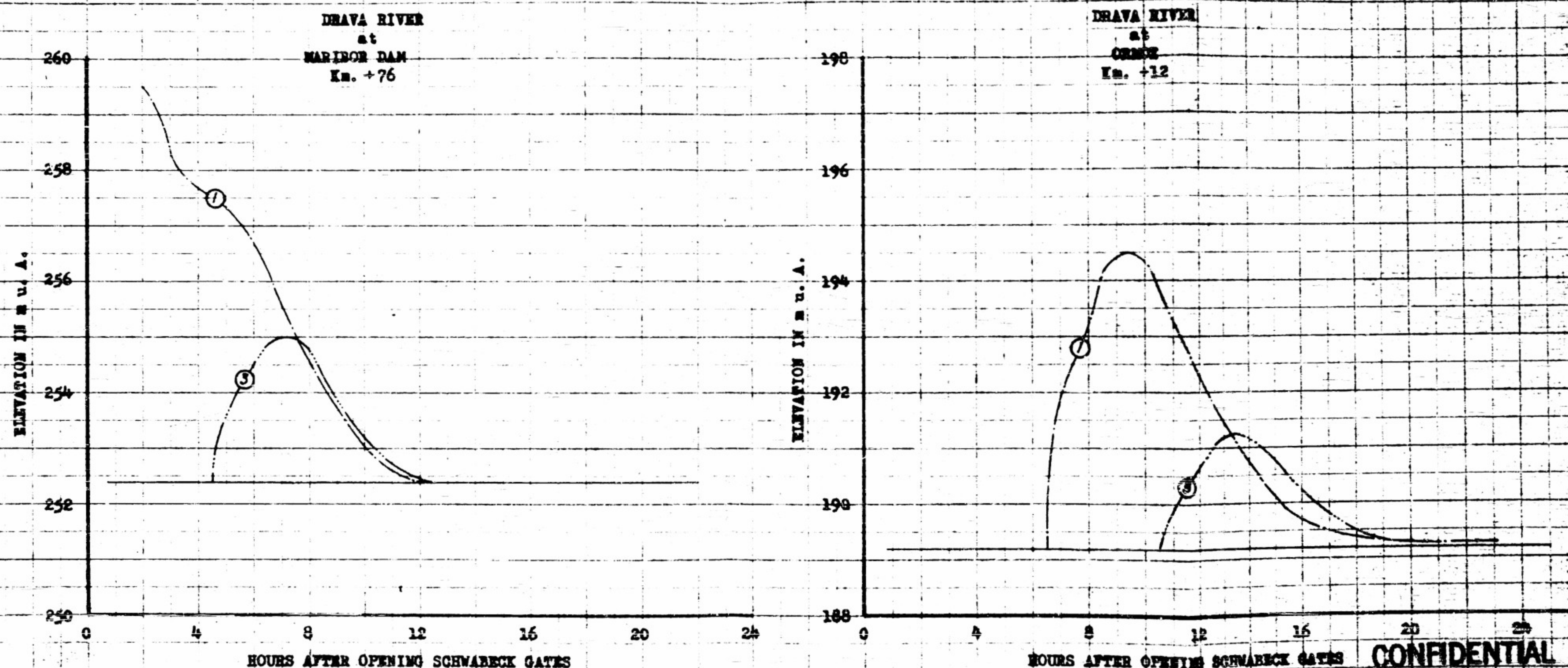


PLATE 12

CONFIDENTIAL
SECURITY INFORMATION



LEGEND

① Artifical Flood No. 1

③ Artifical Flood No. 3

(Refer to Para. 4-03d)

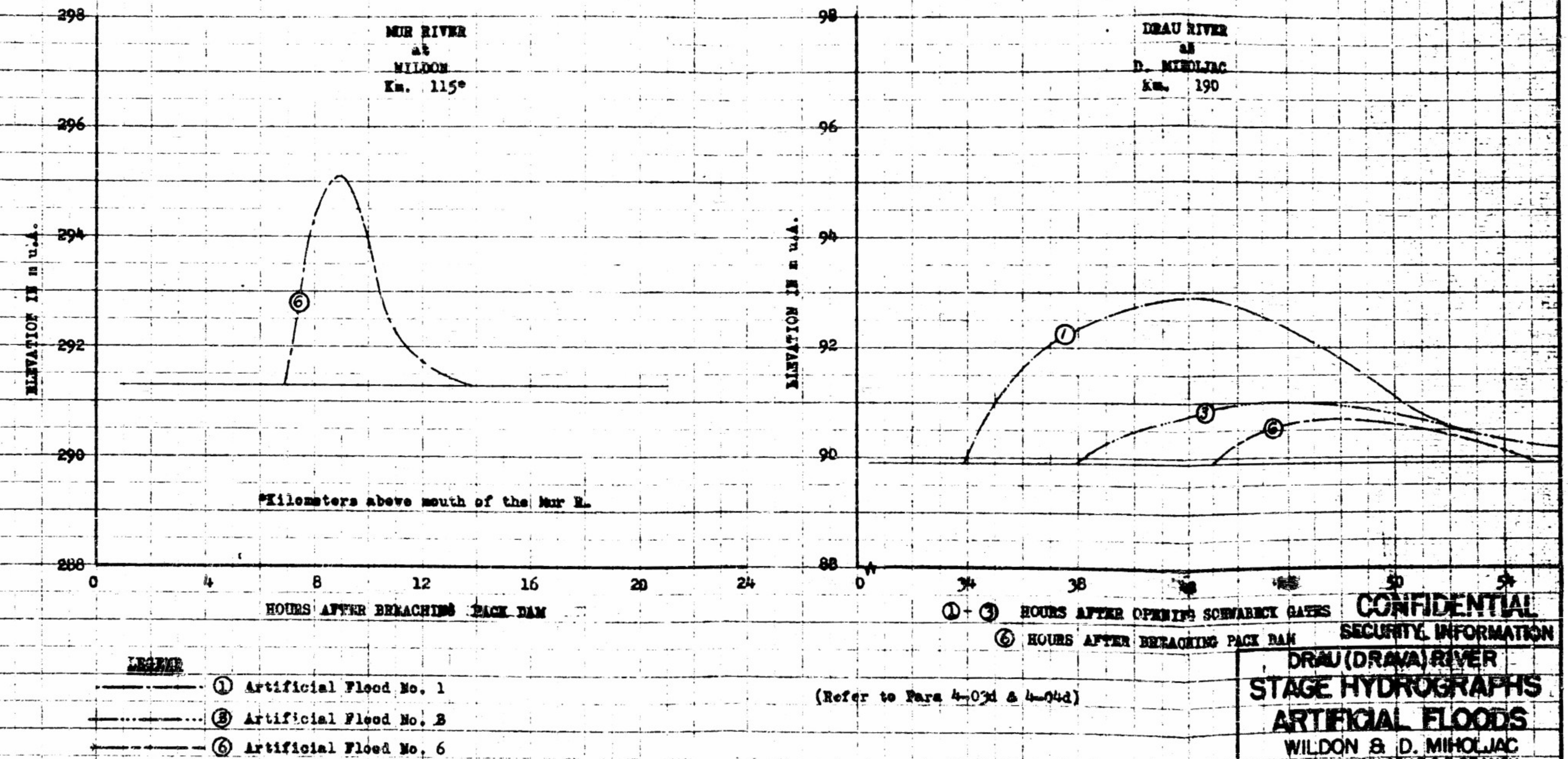
CONFIDENTIAL
SECURITY INFORMATION

DRAU (DRAVA) RIVER
STAGE HYDROGRAPHS
ARTIFICIAL FLOODS
MARIBOR & ORMOZ
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by LOB Date 15 May 1953
Drawn by JJH

PLATE 13 a

CONFIDENTIAL
SECURITY INFORMATION



CONFIDENTIAL
SECURITY INFORMATION

DRAU (DRAVA) RIVER
STAGE HYDROGRAPHS
ARTIFICIAL FLOODS
WILDON & D. MIHOLJAC
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared By JPB Date 15 May 1952
Drawn by JJH

PLATE 13 b

RESTRICTED
SECURITY INFORMATION

EXHIBIT A

ABSTRACTS OF TECHNICAL LITERATURE

ON THE DRAU (DRAVA) RIVER

RESTRICTED
SECURITY INFORMATION

EXHIBIT A

ABSTRACTS OF TECHNICAL LITERATURE
ON THE DRAU (DRAVA)* RIVER

1. INTRODUCTION

a. This exhibit consists of abstracts of information translated from technical literature concerning the physical and hydrologic characteristics of the DRAU (DRAVA) River and the pertinent features of the major hydroelectric power dams in its basin. The information was obtained from American, German, Austrian, Swiss and Yugoslavian technical literature. The sources are listed as References 12 to 14 and 18 to 34, inclusive, in the Bibliography following the text in the main body of this report. In selection of abstracted material, primary emphasis was placed upon hydraulic and hydrologic features that would be of use in the study covered by this report. Reference should be made to the basic sources for other critical features, such as structural and electrical factors. The information available in the sources in many cases is incomplete. However, it is believed that the material presented in this exhibit would assist in determining the relative military hydrologic potentialities of the hydraulic and hydroelectric developments now existing or proposed, within the basin. In addition, this exhibit might be utilized to supplement information obtained from other sources and from field reconnaissance or to serve as a guide to indicate the nature and extent of desirable additional data to be supplied by further research and intelligence procurement.

b. Specific reference is also made to the general map, Plate 1 of the report, for locations of important elements and to Table 4 of the report for summarized pertinent data on hydroelectric structures. Serial numbers of hydroelectric power developments as shown in Table 4 and Plate 1 of the report are included in this exhibit to facilitate identification. The river kilometers cited in this exhibit correspond to the system used throughout the report and described in paragraph 1-04e of the text.

2. HISTORICAL BACKGROUND (Basis: References 12 & 13)

a. The DRAU (DRAVA) River is an international river. It originates in Austrian territory and joins the DANUBE in Yugoslavian territory. It serves as the international boundary between those two countries for 5 km between DRAVOGRAD and LAVAMUEND. The DRAU River, together with its major tributary, the MUR (MURA) River, also forms the international boundary between Yugoslavia and Hungary. The exact location of that border is highly controversial, as the boundary line does not follow the center of the stream but changes from one bank to the other of the many river meanders in this so-called PANNONIAN DEPRESSION.

*DRAU is the German and Austrian name; DRAVA is the Slavic name.

b. Until 1918, the DRAU River course lay entirely within AUSTRIA-HUNGARY; however, because of the dual character of the monarchy, the river was administered from 2 different hydrographic offices; one in VIENNA for the Austrian part, the other in BUDAPEST for the Hungarian part.

c. In 1941 YUGOSLAVIA was overrun by German Armed Forces. They demanded an immediate power development of the DRAU River, to utilize the very favorable hydrologic conditions between SCHWABECK and MARIBOR. This development started in 1938 (after the German seizure of Austria), by construction of a power plant at SCHWABECK (Serial No. 1) and was continued in 1941 by construction of the LAVAMUEND, DRAVOGRAD (DRAUBURG), and MARIBOR (MARBURG) dams (Serial Nos. 2, 3 and 6). The FALA (FALL) power plant (Serial No. 5) existed since 1919. With the exception of MARIBOR, this entire development was completed by 1944. The government of YUGOSLAVIA finished the MARIBOR plant in 1949 and put it into operation (see the general map, Plate 1 of this report for locations).

d. Besides those 5 power plants (namely SCHWABECK and LAVAMUEND now on Austrian territory, and DRAVOGRAD, MARIBOR, and the previously existing FALA now on Yugoslavian territory), the Germans, together with the Austrians, were planning 4 additional power plants: at SALDENHOFEN (VUZENICA), WUCHERN (VUHRED), FRESEN (BREZNO) and ST. OSWALD (SV. OZBOLD). Of these, VUZENICA (Serial No. 4), is now under construction, following the original German plans.

e. The Austrian portion of the DRAU River is under the administration of the Hydrographic Office of Austria (Hydrographische Zentral-Buero im Bundesministerium fuer Land und Forstwirtschaft, Wien) located in VIENNA. The Yugoslav part of the river is controlled by the "Soviet Administration of Hydrometeorologic Service of Federal National Republics of Yugoslavia" (Savezna Uprava Hidrometeoroloske Sluzbe FNRJ) in Belgrade.

3. GENERAL DESCRIPTION (Basis: References 12 & 13)

a. The DRAU River originates on the TOBLACH PASS, elevation 1192.0 m.u.A., in the Austrian province of TIROL, and flows eastward through a valley known as PUSTERTAL. That valley is marked by vast glacier moraines, and rubble and sand terraces. The river descends very fast through a deepening and narrowing valley; the mean gradient is 0.12 percent until it enters the deep basin of LIENZ (elevation 673.0 m.u.A.), at river Km 369.* Here, it is joined by one of its major tributaries, the ISEL River, a very wild and swift glacial stream, 55 km long, fed by numerous streams, such as the TAUERNBACH, KAISERBACH and others, carrying the outflow of the DREIHERREN, SPITZE and GROSS VENEDIGER glaciers. Some of these tributaries are already developed for hydroelectric power production; others, such as the MATREI and HUBEN power developments are

*Kilometers from 1912 Austrian-Hungarian border as described in paragraph 1-04e of the main body of the report.

still in planning stages or already under construction. (See paragraph 11 of this exhibit).

b. Below LIENZ, the DRAU River valley widens. The stream bed itself is higher than most of the valley floor, which results in frequent flooding of the valley. At OBERDRAUBURG (Km 350), the valley again narrows and the river crosses from the Austrian provincial boundary from TIROL into KAERNTEN (CARINTHIA). At KLEEBACH (Km 318), the river turns northward to SACHSENBURG (Km 312), where it joins the MOELL (MÖLL) River.

c. The MOELL River, 80 km long, originates in the PASTEURZ GLACIER in the HIGH TAUERN. It is fed by numerous tributaries, mostly small wild streams bringing the runoff from steep mountain ranges on both sides of the MOELL River or carrying the outflow of high Alpine lakes. The most outstanding tributaries are the REISSECK and KREUZECK stream systems, including the so-called KARSEEN (lakes). Their exploitation for power production is under construction. (See paragraph 11 of this exhibit).

d. At Km 296, the DRAU River is joined by the LIESER River which carries outflow of the MILLSTAETTER LAKE whose area is 13.3 km^2. At Km 279, the WEISSENBACH joins the DRAU River. The WEISSENBACH carries the outflow of the WEISSENSEE, a lake of 6.4 km^2 area and considerable storage capacity. (See paragraph 11 of this exhibit).

e. At VILLACH, Km 258, the DRAU River enters what is known as the "UNTERDRAUTAL," a valley of alluvial character in contrast to the glacial character of the DRAU valley upstream from that place. The valley is outlined on the south by the bare and steep slopes of the KARAWANKEN MOUNTAINS. The SATTNITZ HILLS parallel the DRAU River on the north.

f. At Km 255 on the left side, the DRAU is joined by the TREFFENBACH. That stream carries the outflow of OSSIACHER SEE, a lake of 10.6 km^2 area. The confluence of the GAIL River, the largest right bank tributary of the DRAU River, is located at Km 253. The GAIL River is 115 km long. On it is located FAAKER LAKE, 2.2 km^2 surface area, a lake now being developed for hydroelectric power. (See paragraph 11 of this exhibit).

g. The DRAU River then flows through the KLAGENFURT basin. That basin extends to JAUNTAL and has a floor elevation of 449.0 m.u.A. At the lower end of the basin, the DRAU is joined by the LAVANT River at Km 188. The LAVANT River drains the STUBAI ALPS. Then for 4.6 km, the DRAU serves as the international boundary between AUSTRIA and YUGOSLAVIA. At Km 142, the DRAU crosses the present boundary into YUGOSLAVIA.

h. For approximately 65 km between DRAVOGRAD and MARIBOR (MARBURG), the DRAU River is encased in the escarpment between the POHORJE PLANINA (BACHER GEBIRGE) on the south and POSSRUCK on the north.

3h

The valley, because of its geological character, is unusually suitable for power development; as was planned and partially executed by the Austrians and Germans and, since 1945, has been developed by the government of YUGOSLAVIA.

i. The DRAU valley widens below MARIBOR into the basin of PTUJ (PETTAU), floor elevation 221.0 m.u.A. At VARAZDIN (Km -7), the DRAU River enters the great plain of PANNONIA and flows along the Slavonian range to LEGRAD (Km -55), the junction of its greatest tributary, the MUR (MURA) River. From LEGRAD to SVETI JURAJ, the DRAU River flows between YUGOSLAVIA and HUNGARY and forms numerous meanders because of unprotected banks. From SVETI JURAJ to OSJEK (elevation 94.0 m.u.A.), the DRAU meanders are straightened by regulation. At OSJEK, the flood zone of the so-called "MALA DUNAV," begins. The actual junction of the DRAU with the DANUBE River is approximately 20 km from OSJEK.

4. GEOLOGIC CONDITIONS (Basis: References 12 & 13)

a. The DRAU River follows what is known as the "DRAUZUG" (DRAVA TRAIL). That begins at TOBLACH PASS at INNICHEN. Here originates the division between the CENTRAL ALPS of the north and the DOLOMITES of the south. The southern range is called "KARNISCHE ALPEN" (CARINTHIAN ALPS). It is mostly Devonian limestone, and extends east approximately 100 km to the GAILITZ BREAK. The south watershed of the DRAU basin follows that ridge; the GAILTAL ALPS run parallel to the "KARNISCHE ALPEN." They are predominantly Triassic limestone and dolomite, and actually forms the southern limit of the DRAU valley as far as VILLACH (Km 257). The DRAU valley is the longest Alpine valley, and forms the geological boundary between the Arcaic rock of the CENTRAL ALPS and the limestone of the SOUTHERN ALPS. Only where the DRAU makes a sharp turn into the MOELL escarpment at SACHSENBURG is Arcaic slate apparent on both sides. The valley itself is of glacial origin as evidenced by numerous wide terraces reaching up to heights of 900 m.

b. At VILLACH, the DRAU River enters the KLAGENFURT BASIN, 75 km long and approximately 20-30 km wide, the largest basin of the EAST ALPS. Its south side extends to the foot of the KARAWANKEN MOUNTAINS. Its floor elevation is 400-500 m.u.A. At the north edge of the basin, we find Mesozoic limestone. The inner parts consist of Tertiary sediments and conglomerates (Sattnitz conglomerates). The whole KLAGENFURT basin is of glacial origin and the erosion effect of the receding DRAU glacier resulted in formation of several glacial valleys and scarps. One such valley is the GLAN VALLEY with the OSSIACHER LAKE, another valley accommodates the WOERTHER LAKE, and another known as ROSENTHAL includes the bed of the DRAU River. The former VILLACH LAKE disappeared, leaving behind marshland and a few small insignificant ponds. The 11 km long OSSIACHER LAKE is but 46 m deep. The 17 km long WOERTHER LAKE, without any tributary, consists of two basins of 84 and 73 m depths. Marshes also cover the ZOLLFELD, north of the KLAGENFURT basin. Another

characteristic of the KLAGENFURT basin is the glacial drifts in the forms of moraines with large rubble and gravel fields and fans, and the small glacial basins with marshes or peat or with small lakes. The steep wall of KORALPEN encloses the KLAGENFURT basin on the east, and the DRAU River enters a narrow valley cutting through the crystalline schists and gneiss. These are the basic substances of the POSSRUCK and the BACHER GEBIRGE. The northern part of the former POSSRUCK reaches to an elevation of 1049 m.u.A., and the latter to 1548 m.u.A. The river bed in this part follows a Tertiary seabay, the sediment of which is noticeable in 200-300 m thick layers.

c. Below MARBURG (MARIBOR), the widened DRAU valley enters what is known as the PTUJ FIELD (PETTAUER FELD), an approximately 260 km^2 area, consisting of a sediment fan, bedded in a basin eroded by glacial action. The lowest part of this area is marked by sinks or sumps. At MARBURG, the DRAU bed lies approximately 35 m under the level plain, at PTUJ (PETTAU) 10 m. Below PETTAU, the DRAU valley widens and its alluvial bed acts as a sump for the drainage of the adjacent terrain.

5. HYDROLOGIC CONDITIONS (Basis: References 12 & 13)

a. The discharges of rivers in the DRAU River basin for the 1924-1933 period are given in Reference 13 as follows:

	Reach Length km	NW m^3/sec	MW m^3/sec	HW m^3/sec
ISEL R. at LIENZ	49	11	64	149
MOELL R. at KOLBNITZ	55	7	31	220
DRAU R. at VILLACH	135	20	168	860
DRAU R. at LAVAMUEND	240	130	294	540
GAIL R. at FEDRAUN	100	16	35	290
GURK R. at RAIN	100	15	20	30

b. The runoff coefficient of these Alpine rivers is considerably higher than in South-Central Europe, reaching 50-75 percent, compared to a coefficient of 25 percent in the German lowlands and 40 percent in the central mountainous parts of Germany. This can be explained by the high proportion of glacial flow. Consequently, the evaporation is low and is confined to the summer period. The runoff coefficient of the DRAU River at VILLACH is 71 percent, at LAVAMUEND 62 percent. The yearly discharge of the DRAU at LAVAMUEND is 9.27 km^3 for the 12,000 km^2 drainage area as shown on the graph on page 140 of Reference 13.

c. The winter is the period of low water for all streams in the DRAU region. This is due to ground freezing and also to the long duration of snow cover. The period of low water is usually longer than the period of high water.

d. Two yearly maxima may be noticed at the VILLACH gage: one in late May or early June, and the second in July, on account of summer rains. Between these peaks there is a sharp decline. At the same gaging station at VILLACH the total yearly discharge in the wet year of 1917 was 6,729 million m^3, and the daily maximum flow was 88 million m^3. However, in the dry year of 1921, the yearly discharge fell to 3,066 million m^3 and the maximum daily discharge to 30 million m^3.

e. Observed flood water data on the DRAU River as given in Reference 13 are:

River	Gage	cm above MW	Date
DRAU	OBERDRAUBURG	300	18 November 1882
do	VILLACH	440	2 " 1851
do	ANNABRUECKE	500	13 October 1889
do	LAVAMUEND	650	3 November 1851
MOELL	MOELL BRUECKE	260	14 October 1903
GAIL	MAUTHEN	620	20 " 1896
LAVANT	KROTTENDORF	310	15 July 1926

6. SCHWABECK POWER PLANT (Basis: Reference 18)

a. General

(1) SCHWABECK Power Plant (Serial No. 1) was planned in 1938 and was built in the period 1939 to 1943 during World War II as a war project. It lies in a part of Austrian territory that was annexed by the Germans during the war.

(2) The dam utilizes the steep gradient of the DRAU River between TEUFELSBRUCK (4 km upstream from VOELKERMARKT) and PIRKSCHMIDT (7 km upstream from LAVAMUEND). The pool of SCHWABECK Dam extends upstream 20 km in a narrow valley nearly entirely unpopulated.

(3) In accordance with comprehensive wartime planning of the Germans for DRAU River developments, the SCHWABECK Plant was developed as a pilot plant in a chain of 5 hydraulic developments built or improved from 1939 to 1943 between VOELKERMARKT and MARIBOR (MARBURG). For this purpose, the SCHWABECK Plant was designed to impound the flow of the DRAU River in a retaining reservoir of 25 million m^3 capacity. Out of this total volume, only 5 million m^3 was to be utilized for power generation. The water impounded in the SCHWABECK pool was also intended to serve the other downstream power plants: LAVAMUEND, DRAVOGRAD (DRAUBURG), FALA (FAAL) and MARIBOR (MARBURG), Serial Nos. 2 to 6. The last three were ceded to YUGOSLAVIA after 1945, and difficulties arose on account of the water supply to those plants from the SCHWABECK pool. No agreement has yet been reached as to the disposition of this water between AUSTRIA and YUGOSLAVIA.

(4) SCHWABECK is constructed as a so-called "power plant in the stream" (Kraftwerk in Strom), a type of hydraulic power utilization by means of direct river flow (without penstock), regulated by a movable weir. In the case of SCHWABECK, the power generating part of the development is located in a river bay near the river bank. This type of plant is called a "Buchten Kraftwerk" (bay power plant). It is to be noted that the "power plant in the stream" type of hydroelectric power generation is used on all of the DRAU River power plants mentioned above as well as on many other developments in AUSTRIA and GERMANY.

(5) SCHWABECK PLANT is located in a flat curve of the DRAU River at Km 153, just above the mouth of the JERBIC STREAM. (See figs. 4 & 8, pp 64 & 72 of Reference 18 and Fig. I on Plate 9a of this report). The center of the weir coincides with the river centerline. The power plant is located on the outside of the river curve, wholly within a bay; consequently, is outside of the highwater flow and is separated from it by a dividing pillar.

(6) The 3 vertical power units generate 10,000 volts polyphase current which is conducted by cable to an outside transformer where it is changed to 110,000 volts. The transformer is located on high ground on the left side of the river. The observation or control house is located on the left bank in a straight line continuation of the upstream side of the dam-axis and is connected with it through a subterranean gallery running beneath the entire structure. The workshop of the plant is situated on the JERBITZ STREAM.

(7) The upper pool elevation is limited to 371.0 m.u.A., in view of the conditions at the upstream end of the pool. Any higher stage would flood the plains at VOELKERMARKT. At the upstream end of the pool 20 km above the dam, there is an 8 m high fall in water surface, the top of which is at 380.00 m.u.A. The banks of the DRAU River, upstream from the dam, are steep and high and no specific protection structures are necessary. The backwater effect of the pool extends 20 km to TEUFELS bridge at NW and approximately 15 km at HHW. The village of PIRK, located at the upper end of the pool is so high above flood stage that flooding conditions are not expected. It is assumed, however, according to experiences gained at FALA, that progressive silting of the stream-bed will cause the river gradient to decrease; consequently, the stages at HHW will increase. Therefore, the bridge over the LIPPITZ Stream was elevated 2 m.

b. Hydrologic and Geologic Conditions.

(1) The drainage area of the DRAU River at SCHWABECK is 11,000 km^2. The nearest gaging stations are at the LIPPITZ Stream Bridge and LAVAMUEND Bridge. The flow of the DRAU River at LIPPITZ in the period from 1927-38 was as follows:

6b(1)

Stage	Period	Flow (m^3/sec)
NNW	(1927-1938)	62
MNW	do	77
MW	do	274
HW	1927-1938 (approx.)	600
MHW	(1927-1938)	1500
HHW	(1852)	4500-5000

(2) The 6 months discharge averages, according to official reports, 234 m^3/sec. The flow exceeds the design power flow of 300 m^3/sec for 125 days a year. A discharge of 1,500 m^3/sec was adopted as the basis for determining the crest of cofferdams during construction. That flow had been exceeded 36 days during the period 1896-1938.

(3) According to measurement made at FALA Dam, the mean yearly bed sediment amounts to 150,000 m^3. Ice conditions were noted to be particularly severe in the years 1928-29, also during 1932 and 1939.

(4) Careful studies and extensive model investigations in the technical universities at KARLSRUHE and VIENNA were made to determine the effect of erosion on the bed below the dam. The unusually high discharge of 70 m^3/sec per m of weir width was taken into account in the design of pertinent parts of the structure.

(5) Because of the high and steep banks on the left side, the weir structure was anchored directly to the rock. On the right side, however, it was necessary to develop a structural wing secured against the undercurrents. On that side the anchorage of the weir structure to the rocky bank is located approximately 250 m upstream. The conglomerate found in the immediate surrounding development is so densely compacted that it could sustain a load up to 1 kg/cm^2. At greater depths, an artificial consolidation to the solid rock was necessary.

c. Features of Fixed Weir.

(1) The total lengths between the dividing pillar and the right side face is 90.00 m. The weir consists of: 4 openings each 18.75 m wide; 3 mid-stream pillars 5 m each wide (see Fig. 1 on Plate 9a of the report or Figs. 8, 9, 10, pp 73 & 77 of Reference 18). The fixed weir sill has a crest elevation of 357.00 m.u.A., 9 m above the original river bed. On top of the fixed weir is a 14 m high movable gate structure. This arrangement proved to be most efficient and most economic in view of the 22 m high design hydraulic head (the mean head is 20.5 m).

(2) Complete emptying of the pool is accomplished by a scouring sluice located in the power plant part of the weir. That sluice is large enough to pass the normal DRAU River flow without overtopping the weir sill. The lip elevation of the scouring sluice is 354.00 m.u.A.

(3) The crest of the fixed weir is shaped so as to permit the maximum discharge and at the same time to allow the gate to slide on the back of the sill. The radius on the downstream side of the weir is 10 m; the lower slope is 1 to 1.

(4) The tailwater level never exceeds the crest of the weir. Consequently, the hydraulic conditions represent a free overflow. In the formula $Q = 2/3\ c\ (2g)^{0.5} H^{1.5}$ the value of $2/3\ c(2g)^{0.5}$ is equal to 2.20 (c = 0.74) in metric units. At full opening of the weir, the nappe thickness is 7.75 m. When only 3 spans are open, the upper water level is 368.75 m.u.A., and the elevation of the nappe at the crest is 366.25 m.u.A., representing a nappe thickness of 9.25 m. This is 0.75 m under the lowest edge of the gate when it is in raised position. A gallery through the fixed weir permits inspection of the structure, particularly of the expansion joints. Also additional injections can be made, if necessary.

(5) The fixed weir is rounded on the tailwater side into an apron located at elevation 344.0 m.u.A., approximately 4 m below the original river bed. The apron ends with an indented granite sill which proved to be successful in preventing scouring effects.

(6) Percolation beneath the weir foundations was prevented by injections of grout to create an impervious curtain. Three anchors tie the entire structure to the foundation rock.

(7) The weir pillars are 5 m thick, half-circular on the upstream side. In order to achieve better flow pattern, the pillars narrow downstream to a 3 m thickness. They are horizontally and vertically reinforced by steel bars. The bridge across the weir is of reinforced concrete with rails for transportation of heavy machinery.

d. Features of Weir Gates.

(1) The weir openings can be closed by double sluice gates (Doppel Schuetzen). These gates are composed of 2 vertical sliding leaves. The upper leaf is equipped with a hook-shaped upper crest (at closed conditions, its elevation is 371.30 m.u.A.). When lowered along the upstream side of the lower leaf, the top lies at elevation 365.80 m.u.A. Under this condition, the weir can pass 1,900 m^3/sec discharge when the pool stage is 371.0 m.u.A. The flow at MHW is 1,500 m^3/sec, which can be passed by lowering of the upper leaf. Only in very exceptional cases, when the flow equals or exceeds 2,200 m^3/sec (1900 m^3/sec plus 300 m^3/sec turbine capacity), does the lower leaf of the gate have to be raised. A flow of 2,200 m^3/sec corresponds to ten years MHW. At full opening, the lowest edge of the gates is located at elevation 367.00 m.u.A. The catastrophic flow of 5,000 m^3/sec passes over the weir approximately 1.5 to 2 m under the lowest edge of the movable gate structure in raised position.

6 (2)

(2) The lower leaf of the gate is constructed of 4 steel bands, supported by horizontal main girders on the downstream side. The water pressure is carried to the pillars by means of 4 carriages moving on 8 rollers.

(3) The hook-shaped upper leaf of the gate has only 1 horizontal girder on the downstream side. The water pressure is carried to the vertical ribs, supported partly on the main girder and partly by means of rollers on the lower leaf of the weir. The upper leaf is also equipped with rolling carriages. The top of the upper leaf is 27.30 m higher than the apron of the downstream stilling basin.

(4) The carriages supporting the lower and upper leaves move on a common track, permitting a simple construction of the pillar recess. The main girders have 19.80 m spans and are equipped with swing-supporting bearings so that the gate structure may deform in any direction without influencing the perpendicular position of the rollers at the rail track. The expected roller pressure is 210 tons. The cast steel rail has a supporting width of 0.350 m.

(5) The seal between the upper and lower leaves consists of a rubber ledge; the side seal consists of milled steel anchors. A leather belt takes care of fine sealing. The bottom seal is an oak log fitting against a steel plate and anchored to the concrete of the fixed weir. Aeration beneath the nappe is effected by air shafts in the pillars. These shafts are accessible from the concrete bridge.

e. <u>Features of Gate Operating Equipment</u>.

(1) The machinery for raising the gates travels across the weir openings on a plate-truss bridge. The elevation of this bridge is established by the highest position of the double sluice gates; hence, its floor has an elevation of 378.50 m.u.A. The hoisting machinery is accessible from both sides.

(2) The lifting forces involved are 134 tons for the upper leaf and 202 tons for the lower leaf, including a safety factor. Each leaf has a separate hoisting mechanism and all 8 leaves may be independently lifted at the same time.

(3) The hoisting machinery is located on both sides and consists of pinions with an enclosed worm-gear drive operating in an oil bath. In the middle is an electric motor operating both hoists. The necessary accessories (such as: reduction gears, sliding clutches, electromagnetic brakes, etc.), are designed to achieve easy weir operation. An auxiliary diesel is provided to supply power if the regular power supply should fail.

f. Emergency Provisions for Weir Closure.

(1) To permit emergency closure and repairs on the upstream side of the weir, there are 4 stop-logs each 3.75 m high. They are moved into position by means of a portal crane. Each stop-log has 2 trusses (I-37) covered with steel plates. The stop-logs are stored on the left bank.

(2) The downstream closure of the weir consists of needles (I-20), covered with wood on both sides. The bottoms of the needles are supported by a sill and the tops by a horizontal girder across the weir opening. Its span is 21.25 m. This downstream emergency closure facilitates the separation of the structure from the tailwater to a stage of 350.50 m.u.A. The supporting girder is moved across the concrete bridge by a crane and then slid down the inclined end of the pillars into its position. For this reason, the railing of the concrete bridge is removable. The needles are placed in position by means of a hand-operated windlass moving on the supporting girder.

(3) The portal crane serves for moving of stop-logs and operates on the upper part of the main truss of the hoisting bridge. The stop-logs are seized by a "plier tong" and placed in the recess of the pillar and slid on rollers into position. The level mechanism permits the locking and unlocking of the stop-logs either above or below the water. The crane also performs other functions in servicing of the weir. All steel parts of the weir were specially constructed by "MAN" (Maschinenfabrik Augsburg-Nurenberg A.G.).

g. Features on Right Abutment of the Weir.

(1) The right abutment of the weir (see fig. 8, p 86, Reference 18) has a 45° inclined wing on the upstream side. It extends 10 m below the tailwater apron. The top of the abutment is 1.30 m above the crest of the movable weir and 24.3 m above the foundation. The downstream part of the side wall has a top elevation of 350.5 m.u.A., 1.50 m over HHW.

(2) An emergency power plant and steps are also located at the right end of the weir. The steps rise from elevation 352.00 m.u.A. at the bottom, to a platform at elevation 359.00 m.u.A., then to the emergency power plant at elevation 368.20 m.u.A., and finally to the pillar structure and servicing bridge at elevation 378.50 m.u.A.

(3) The cooling water supply plant is located on the right abutment. The filtered water is pumped in a reservoir in which the stage is automatically held constant at 370.40 m.u.A. A fish pass is also located on the right side of the weir.

h. Features of the Power Plant.

(1) The dividing pillar has a length of 84.64 m and a top elevation of 338.00 m.u.A. It extends 25 m below the downstream outlet of the draft tube.

(2) The general arrangement of the power plant is outlined on figs. 1, 8 and 11, pp 62, 73, 87, Reference 18. The power plant is designed for 300 m^3/sec flow and has three generating units. At MNW, the flow is 80 m^3/sec. The total length of the power plant normal to the river is 56.00 m; the distance between the units is 13.00 m. The power plant, including the dividing pillar, is structurally developed as a frame unit, parted by a joint located along the weir side of the dividing pillar. The total length of the power plant parallel to the river flow is 50.9 m from the front wall of the inlet to the end of the draft tube. A continuous construction joint lies 7.00 m upstream from the turbine axis. The hydraulic and electric generating parts of the plant are separated by a reinforced concrete slab with the upper floor at elevation 357.00 m.u.A. The performance of the plant under varying stage is given in fig. 12, p 19, of Reference 18.

(3) The turbines are Voith-Kaplan type with vertical shafts, rotor diameter 4.080 m, 167 rpm, specific speed 600. The 6 turbine blades are adjustable. The generators produce 10,000 volts. At 300 m^3/sec, the maximum performance is 51,000 KW and at 375 m^3/sec (with a head of 20.59 m, slightly more than the normal head), the performance is 61,300 KW. At MNW, the power capacity is 20,000 KW.

(4) Each turbine includes an inlet, spiral concrete conduit and draft tube. The inlet is divided into 2 parts for better distribution of the flow. The inlet lip elevation is 360.0 m.u.A., 3.00 m above the crest of the fixed weir. Flow passes through a trash rack (whose upper edge is 2.00 m under the normal stage of 371.00 m.u.A.) and enters into the inlet tube and then into the spiral conduit. This concrete spiral-conduit has a rectangular cross-section with rounded corners and is dimensioned so that the overall velocity with a flow of 100 m^3/sec is 0.85 m/sec at the fine trash rack and 3-4 m/sec inside the conduit. After passing through this 4.50 m high spiral-conduit, the flow enters a guiding case, turns 90° in the axial direction through the runner and then into the draft tube. At the draft tube entrance, the normal velocity is 7.60 m/sec, and at maximum opening, the velocity becomes 9.50 m/sec. The circular cross-section of the draft tube changes into an oval and ultimately into a rectangular cross section with rounded corners. In places where the velocity exceeds 6 m/sec, the draft tube is reinforced by steel armor. The rising angle of the draft tube is developed in such a way that it permits a quiet outflow at 2 m/sec velocity.

(5) Generator supporting rings are placed over the spiral conduit. These support the machine load and the torsion, particularly torsion resulting from short circuits. These supports are of quadratic

6h(5)

form on the outside leaving a free recess between the machinery. In these recesses are placed the governors, the oil pumping units, the air chambers, and a compressor installation serving all 3 machine units.

(6) A continuous scouring channel is located beneath the inlet sill. This serves for collection of deposits accumulated in front of the turbine inlet. The entrance into the scouring channel has a maximum hydraulic efficiency of 120 m^3/sec. The entrance is near the dividing pillar, and takes off towards the left bank along a parabolic curve. The entrance to the scouring channel is steel-armored and all surfaces are treated with "torcret" (a special surfacing material).

(7) A 3 m wide frame-shaped superstructure over the main pillars supports the power plant bridge. The bridge is a continuous truss of 4 spans. The pillars of the inlet structures are connected by a concrete bridge permitting the transportation of stop-logs for the turbines.

(8) The inlet into the turbines and draft tubes can be separated entirely from the upper pool and tailwater for purposes of repairs. The inlet can be pumped dry after stop-logs are placed at the turbine inlets. If a turbine fails, the water inflow is automatically reduced to 30 m^3/sec. At this rate of flow, the stop-logs can be inserted. This operation takes approximately 5 hours. During this operation, the turbines run at 220 rpm. In order to achieve the sinking of the stop-logs at least 4.50 tons of weight are required to sink them into position. The stop-logs are handled by a windlass on a carriage and are placed into position by the crane.

(9) The scouring chanel is 1.5 m high and has a floor elevation of 354.00 m.u.A. Because of the high pressure head of 17.00 m, the inlets to the scouring channel are armored and provided with additional air vents. The lifting mechanism consists of a windlass and a rack placed in a recess. The air vents are 0.20 m diameter pipes. To achieve a complete closure of the powerhouse, a set of 4 stop-logs on rollers, each 4.30 m long can be placed in front of the scouring gate. These stop-logs consist of a plate truss covered by a steel skin and are equipped with rollers and moved by the crane.

(10) The fine trash rack in front of the turbine entrance consists of flat iron bars. The clear distance between bars is 0.08 m. The rack can be elevated by means of a mechanism attached to a crane for purpose of cleaning, particularly during ice formation.

(11) The tailwater side of the turbines can be completely closed by an emergency gate located 4.00 m from the end of the draft tube. This emergency gate consists of 2 sliding steel leaves of 4.60 m clear width and 3.25 m height. It has 2 valves permitting the balancing of pressure after the draft tube is pumped dry, in order to facilitate opening. The spiral conduits and the draft tubes are emptied by pumping units with a capacity of 0.4 m^3/sec at 16 m head. The "MAN" movable bridge crane

has a 13.50 m span, and handles the equipment necessary for servicing of individual parts of the power plant. The crane has a hoisting capacity of 140 tons and is placed on 4 carriages with 16 wheels.

7. LAVAMUEND POWER PLANT (Basis: References 19, 20 & 21)

a. General.

(1) LAVAMUEND (Serial No. 2) is one of the large power plants of Austria built by the Germans in the period 1941-44 as a war project, simultaneously with SCHWABECK, DRAVOGRAD and MARIBOR. As a result of the war, the boundary of Austria was re-drawn near LAVAMUEND. Its production of power was affected by the fact that its twin plant, located just downstream at DRAVOGRAD, was ceded to YUGOSLAVIA.

(2) The project was built as a "pillar power plant" (pfeilerkraftwerk) in which the power units are located in pillars in the midstream of the river. The LAVAMUEND and DRAVOGRAD (DRAUBURG) plants are of the same type and dimensions.

(3) The major characteristics of the LAVAMUEND plant are: (a) location: Km 147, (b) hydraulic head: 9.0 m (8.5 m for power calculation, (c) maximum capacity of the turbines: 384 m^3/sec (300 m^3/sec normal operation), (d) flow capacity of the weir at HHW: 5,000 m^3/sec, (e) four weir openings: each 24.00 m clear width, 11.00 m height, (f) three middle pillars: each 16.00 m wide.

(4) Reference is made to Plate 9a of this report and to Figs. 1 to 4 and 6 to 11, pp 100, 101, 203, 204 of Reference 19 and Figs. 3 & 4, p 177 of Reference 20.

b. Features of Power Units.

(1) The midstream pillars have recesses, supporting the weir gates located upstream from the turbine axis, within the straight part of the turbine conduit. This results in better scouring and better flow pattern and permits shorter stilling apron length.

(2) Protection against drift, ice, and silt is provided by a submerged overhanging wall shaped like a ship's bow and by a sill in the stream bed. At high water stages when the upper leaf of the double sluice gate is open, the submerged wall directs the surface flow and all floating objects towards the weir. Similarly, when both leaves of the weir gates are opened, a swift current toward the weir sill causes movement of sediment accumulated in front of the turbine entrances and thus clears the river bed.

(3) The spiral form of the turbine conduit requires an offset position of the turbine axis (see figs. 2 & 4, p 203, Reference 19).

7b(3)

For this reason, and also because of the limited width of the pillar and in order to develop better stream flow pattern, the shape of the rectangular spiral conduit was made narrow and high. The same consideration was applied to construction of the draft tube.

(4) The emergency closure of the turbines is effected by stop-logs. They have the same angle of inclination as the trash rack. Placing and removing is performed by a movable crane. The trash rack has 0.10 m clear width of openings. It can be removed in wintertime and can be placed in position during turbine operation. On the downstream side, the other emergency closure is located at the curve in the draft tube where the cross-section size increases. This needle dam closure separates the draft tube from the tailwater. These closures permit the entire power units to be pumped dry for inspection or repairs.

(5) The power units consist of Kaplan turbines with vertical shafts. The generators and turbines are coupled on a common shaft supported by two neck bearings. The footstep bearing is located on the turbine cover, supported by the guide blade ring. The three Kaplan turbines have each 128 m^3/sec flow capacity at 9 m hydraulic head and at 100 rpm, 7,800 KW power capacity. The overall power capacity is 24,000 KW or 138,000,000 KWH per year.

c. <u>Features of the Weir</u>.

(1) The total length of the LAVAMUEND dam is 144.0 m between abutments. The dam has 4 weir openings, each of 24.00 m clear width, and 3 midstream pillars, each 16.00 m wide (see Plate 9a of this report or Fig. 11, p 208 and p 177 of Reference 20). The damming of the stream is done by a movable double sluice gate similar to the gates used at SCHWABECK and other power plants on the DRAU River. The gates can be moved independently by hoisting machinery and raised up between the main beams of the upstream weir bridge. The specialized construction of the hoists and weirs permits an unusually low position for the hoist (only 1.40 m over the gate tops).

(2) Emergency closure of weir openings is effected by stop-logs placed in position by a crane. When not in use, the stop-logs are stored on the right embankment. The weir may be separated from the tailwater by an emergency needle-dam. The needles are wide-flange I-beams, wooden fitted, supported in position by the weir sill and by a movable horizontal truss similar to that at SCHWABECK.

d. <u>Hydraulic Design Data</u>.

Following is the basic hydraulic design data used for calculation of LAVAMUEND weir flow:

7d

(1) Cross section area of weir gates:
$F_w = 4 \times 24.0 \times 11.0 = 1056\ m^2$

(2) Rake area (measured vertically:
$F_r = 3 \times 11.0 \times 10.0 = 330.0\ m^2$

(3) Utilized flow area: $F_w + F_r = 1386.0\ m^2$

(4) Total cross section area of approach channel:
$F_{ow} = 144.0 \times 11.0 = 1584.0\ m^2$

(5) Ratio:
$f_{ow} = \frac{F_{ow}}{F_w + F_r} = 1.14$

(6) HHW velocity through weir gates: $\frac{HHQ}{F_w} = \frac{5000}{1056} = 4.7\ m/sec$

(7) Velocity through rakes: $\frac{AQ}{F_r} = \frac{300}{330} = 0.90\ m/sec$

8. DRAVOGRAD (DRAUBURG) POWER PLANT (Basis: Reference 21)

a. General. DRAVOGRAD Power Plant (Serial No. 3) is located at Km 136. At present, it stands on Yugoslav territory, 4.4 km downstream from the Austrian border. It was built and developed in the period 1941-1944 when that area was occupied by the German Army and power production was needed for war purposes. It is one link in the chain of power plants developed by the Germans on the DRAU River, simultaneously with the power plants at SCHWABECK, LAVAMUEND and MARIBOR.

b. Features of Structure. The DRAVOGRAD plant is a twin to the LAVAMUEND plant, as local conditions made it possible to make both plants identical in type, size, and basic measurements. Both were constructed simultaneously and all parts such as weir gates, turbines and other machinery and equipment were ordered in double quantity. Concerning the main characteristics, we could consequently repeat the data given for LAVAMUEND in the preceding paragraph 7 of this exhibit, with the exception of the elevations. (See Figs. 1, 4, 10 and 11, pp 202-208 of Reference 21).

c. Features of Power Units. DRAVOGRAD is a "pillar power plant" in which the three midstream pillars of the weir contain the power generating units with turbine and generator coupled on a common vertical shaft. The total clear length of the power development across the river is 144 m, divided 4x24.00 m for the weir openings and 3x16.00 for the pillars.

d. Hydraulic Features. The upper pool stage elevation is 341.50 m.u.A., same as the tailwater stage of LAVAMUEND. The tailwater of DRAVOGRAD is 332.50 m.u.A. The total hydraulic head is 9.00 m, but the mean head for calculation of power was taken as 8.50 m. The flow capacity of the turbines is 390 m^3/sec; however, the normal operation of the power plant is based on 300 m^3/sec.

9. FALA (FAAL) POWER PLANT (Basis: References 22 and 23)

a. General.

(1) FALA Power Plant (Serial No. 5) was built between 1912-1919 and is the first large power plant to be built on the DRAU River between VOELKERMARKT and MARIBOR. The discharges of the DRAU River at the FALA plant location as estimated in 1912 by the Austrian Hydrographic Central Bureau in Vienna were as follows:

over	300 m^3/sec	during	305	days	a year
"	200	" "	315	"	" "
"	150	" "	335	"	" "
"	100	" "	345	"	" "

(2) In the lowest low water period, the discharge dropped under 82 m^3/sec for only 2 days per year. The HHW of the DRAU River is 4000 m^3/sec according to information of the Hydrographic Central Bureau in Vienna. (The 1949 HHW of 5000 m^3/sec was taken into account for construction of SCHWABECK, LAVAMUEND and DRAVOGRAD dams). The mean yearly discharge is 235 m^3/sec. The net hydraulic head at FALA varies between 14.8 and 11.3 m at normal HW; at NNW, the hydraulic head is only 9.00 m.

(3) Between DRAVOGRAD and MARIBOR, the DRAU River breaks through a mountain range, composed of Archean rock and gneiss-type mica schist with amphibolic rock.

(4) The FALA plant was developed as a "bay power plant" (see paragraph 6a(4) of this exhibit), one of the first of this type built in Central Europe. This type was copied in many later structures, especially in AUSTRIA (see Figs. 6, 7, 8, 9, pp 533 and 534 of Reference 22 or Plate 9b of this report). The development consists of a weir plus a power plant located in a bay and accommodating the generating units.

b. Features of the Weir.

(1) The weir has a total clear length of 93.00 m, with 5 openings each of 15.00 m clear width and 4 midstream pillars each 4.50 m wide. The fixed portion of the weir has a crest elevation of 265.80 m.u.A. This is approximately 3.30 m above the rocky bottom of the upper pool bed.

(2) The remaining part of the weir opening extending up to elevation 280.80 m.u.A., is closed by double sluice gates composed of 2 leaves. The upper leaf provides for damming between elevation 280.80 and 276.80 m.u.A. The height of the upper leaf is 4.81 m. The lower leaf provides for a hydraulic head of 11.00 m between elevation 265.80 m.u.A., and 276.80 m.u.A. Both leaves have horizontal trusses covered with steel plates, transferring the hydraulic load to the main weir pillars. The upper leaf can slide behind the lower leaf to permit passage of excess flow. At HHW both leaves can be raised by means of hoists placed on a bridge, elevation 303.00 m.u.A. This is 20 m above the top of the pillars and is high enough to be above flood stage.

(3) Both the upper and downstream sides of the weir have provisions for emergency closure by means of stop-logs. The servicing of the weir is by means of a crane moving across the bridge.

c. Features of the Power Plant.

(1) The power plant of the development is in a bay at the left abutment of the weir. Its total length is 69.30 m. The plant contains 7 twin turbines of the Francis type with horizontal shafts. The turbines are placed in an open pit and the horizontal shafts pass from the pit into the generator room through stuffing boxes (see Figs. 1, 2 and 3, pp 138, 139 and 140 of Reference 23).

(2) The turbine inlets are equipped with scouring sluices, trash racks and emergency closures. Another emergency closure is provided in the draft tube on the tailwater side. The twin turbines have the following performance characteristics:

head (m)	14.8	13.3	11.3
discharge (m^3/sec)	38.5	43.3	40.0
rpm	150	150	150
power (HP)	6000	6000	4500 (with possible increase to 6600 HP)

10. MARIBOR (MARBURG) POWER PLANT (Basis: References 24, 25, 26)

a. General. The MARIBOR (MARBURG) Power Plant (Serial No. 6), also known as "MARIBORSKI OTOK," was started in 1942 by the Germans, together with the other DRAU River plants at SCHWABECK, LAVAMUEND and DRAVOGRAD. The plant was completed in 1950 by the government of Yugoslavia in accordance with the original German plans.

b. Hydraulic Features. The power plant is on the DRAU River 64.3 km downstream from the present AUSTRIAN-YUGOSLAV border, in the immediate vicinity of FELBER ISLAND. The upper pool stage was fixed at elevation 267.20 m.u.A., so as not to submerge the FALA DAM, located a short distance upstream. The mean utilized hydraulic head is 14.40 m. The mean tailwater elevation at MARIBOR is 252.80 m.u.A. (See p 268 of Reference 24 or Plate 9b of this report).

c. Features of Weir. The project is constructed as a "pillar power plant" similar to LAVAMUEND and DRAVOGRAD. The width of each of the 4 weir openings is 18.75 m, the same as at SCHWABECK. The weir height is 14.30 m, identical to that dam, as the Germans planned to use the same type and size of gate structure at both installations. The fixed weir sill of 3.40 m height was built to conform with the required dimensions of the weir openings. The double sluice gates are elevated by means of a mechanical drive located on top of the pillars and are similar to those on the other DRAU power plants developed by the Germans. Flood water may pass freely under the elevated gates. On the upstream side of the weir are 2 concrete-beam bridges accommodating the servicing crane. On the downstream side is an arched bridge for street traffic.

d. Features of Emergency Closures. The emergency closures are similar to those at LAVAMUEND and DRAVOGRAD, and permit a complete separation of the weir and generating units from the upper and lower pools.

e. Features of Power Plant. The power units, located in the midstream pillars, have a power capacity of 50,000 KW at 125 rpm. The three Kaplan turbines with vertical shafts and coupled generators are basically the same as those at the other DRAU River power plants mentioned above. The maximum flow capacity of the three turbines is 410 m^3/sec. The pillars are equipped similar to those at LAVAMUEND with an overhanging submerged wall of ship-bow shape, serving as protection against the drifting ice and other objects at high water flow.

11. MAJOR DEVELOPMENTS ABOVE SCHWABECK (Basis: References 14, 27, 30, 31)

a. GURK River Region.

(1) RAINWERK Power Plant (Serial No. 16) built 1908-1925, 3500 KW capacity.

(2) FORSTSEEWERK Power Plant (Serial No. 17) in operation since 1937, 2000 KW capacity. Located on the outflow from FORST LAKE, utilizing its head above WOERTHER LAKE. WOERTHER LAKE'S area is 19.6 km^2; its outflow, GLANFURT, joins the GLAN River which then flows into the GURK River.

b. GAIL River Region.

(1) GAIL Power Plant at ARNOLDSTEIN (Serial No. 15) "Elektrizitaetswerk in der Schuett," located between Km 15.3-17.5 above the mouth of the GAIL River. Drainage area, 1252 km^2. The river flow is impounded behind the weir and transferred to the turbines by an open canal 1.75 km long. The weir has 4 openings, each 12.0 m wide and 3 midstream pillars, each 2.0 m wide, totaling 54.0 m. The openings have double sluice gates. The inlet channel has 44-46 m^3/sec capacity and the total utilized head is 16.6 m. Four twin turbines with horizontal axes have a total capacity of 7150 HP or 5200 KW (3x1750HP + 1x1900HP). For details, see "Oesterreichischer Wasserkraft Kataster (Gail) 1948," Reference 14, p 621 of Reference 27, or Plate 9c of this report.

(2) RAAKER LAKE Development (Serial No. 23) is in planning stage. The reservoir area is 2.2 km^2 and the storage capacity is estimated to be 30 million m^3. The outflow through the SEEBACH enters the GAIL River at Km 6.0 above the mouth.

c. TREFFNER BACH Region. OSSIACHER LAKE: 10.6 km^2 area at 501.0 m.u.A. elevation; undeveloped.

d. WEISSENBACH Region. WEISSENBACH Power Development (Serial No. 24): Under construction since 1950. It utilizes the favorable conditions of WEISSENSEE (LAKE), located between the DRAU and GAIL valleys. The water power is utilized in 3 stages. The most important is the lowest stage at KAMERING with 162.0 m head. The regulating gate is constructed on the lake. The discharge capacity of the KAMERING Dam is 14.0 m^3/sec. The WEISSENSEE'S area is 6.4 km^2, and its storage capacity is 133 million m^3. There is an additional storage reservoir of 1.3 million m^3. The development operates as a "run of the river" plant. (See pp 50 and 51, Reference 28).

e. LIESER River Region. MILLSTAETTER LAKE: Area 13.3 km^2, estimated storage, 53.0 million m^3. This project is undeveloped. Outflow from the lake flows through the SEEBACH into the LIESER River.

f. MOELL River Region.

(1) MALLNITZ Power Plant (Serial No. 19) at OBER VELLACH MOELL River Km 20.5, operated by the Austrian Railways. Capacity is 20,000 KW. It utilizes the flow of MALLNITZ BACH and KAPONITZ BACH. The total drainage area is 132.7 km^2. The estimated inflows are as follows:

Annual inflow	152 million m^3
Annual mean flow	4.82 m^3/sec
Mean flow (April-September)	7.43 m^3/sec
Mean flow (October-March)	2.2. m^3/sec

The surge tank capacity is 3,800 m^3 at elevation 997.0 m.u.A. The fixed weir at MALLNITZ is 15.0 m wide with a bottom outlet 4.0x4.0 m. For details, see "Oesterreichischer Wasser Kataster (Moell) III-7," Reference 14.

(2) LASSACH Power Plant (Serial No. 18) on MALLNITZ BACH operated by the Austrian Railways, Capacity 2,000 KW. The power plant is developed for 1.20 m^3/sec flow. A tabulation of pertinent data follows:

Drainage area	87.7 km^2
Yearly inflow	111.0 million m^3
Annual mean discharge	3.52 m^3/sec
Mean discharge (Apr.-Sept.)	5.41 "
" " (Oct.-Mar.)	1.62 "
Low water flow (NQ)	0.67 "
High " " (HQ)	24.16 "
Highest high water flow (HHQ)	65.60 "

(3) FLEISSBACH Power Plant (Serial No. 20): Moell River Km 70.0. Power capacity 2,970 KW. This project utilizes the lowest part of the FLEISSBACH gradient between the junction of the GROSS and KLEIN FLEISSBACH, near the village of PACKHORN, 300 m upstream from the MOELL River junction. A tabulation of pertinent data follows:

11f(3)

Drainage area	30.7 km^2
Yearly inflow	45.0 million m^3
Mean discharge	1.42 m^3/sec
High water flow (HQ)	8.0 "
Highest high water flow (HHQ)	29.0 "
Utilized head	331.0 m
Reservoir elevation	1497.00 m.u.A.
Stream elevation below power plant	1135.00 "

This is an auxiliary development to be utilized for power supply during the building of the MOELL conduit to the KAPRUN development and later to supplement that development. The project has a fixed weir, 9.0 m wide and 4.0 m high side abutments. The trash rack has 0.02 m clear openings and is 4.5 m wide and 1.8 m long.

(4) MOELL Transfer Conduit to KAPRUN MOELL River Km 80.0. This development was built in order to utilize the flow of GLOCKNER PASTERZ glacier and the LEITERBACH for the KAPRUN power development in the SALZACH River basin on the north side of the HIGH TAUERN. It was placed in operation in 1952. The MOELL conduit to KAPRUN is a pressure conduit, 2.60 m diameter, 0.34 percent maximum gradient, and 16.0 m^3/sec flow capacity. The main part of this development consists of the damming of the PASTERZ glacier flow and MOELL River by 2 dams, creating the artificial reservoir of MARGARITZE.

(5) MARGARITZE Reservoir (Serial No. 21): has 3.1 million m^3 storage capacity at a pool elevation of 1980.0 m.u.A. The maximum pool elevation is 2000.0 m.u.A. The north dam, "MOELLSPERRE," is an arched gravity type, 77.0 m high and 110.0 m long at the crest. The south dam, "MARGARITZENSPERRE," is 38.0 m high, of gravity type, 95.0 m long. The bottom outlet on the north dam discharges into the MOELL River and is 150.0 m long and has a diameter of 2.20 m. The LEITERBACH is diverted into the MARGARITZE Reservoir by a 1.8 km long conduit of 2.2 m diameter and 3 m^3/sec capacity. (See "Oesterreichischer Kataster (Moell) III 7a," Reference 14 and p 103 of Reference 33).

(6) KOLBNITZ-REISSECK-KREUZECK Power Development (Serial No. 29).

(a) This project has been under construction since 1947 with estimated completion in 1956. It will have 120,000 KW ultimate capacity; the present operating capacity is 24,000 KW. The water power supply can be classified into two groups: the REISSECK Group and the KREUZECK Group. Both utilize the water power of high located Alpine lakes and the swift tributaries of the MOELL River. The central power plant is located at KOLBNITZ. (See "Oesterreichischer Kataster (Moell), Reference 14 or References 29, 32, 33 and 34).

11f(6)(b)

(b) REISSECK Group (Serial No. 29): This consists of the following elements:

	Capacity (million m^3)	Elevation m.u.A.
HOCHALPENSEE	4.7	2377.80 (max.)
RADISEE	2.6	2360.30 (min.)
KLEINE MUEHLDORFERSEE	2.8	2399.00 (max.)
GROSSE	7.9	2388.00 (min.)
ZANDLACHER DAILY RESERVOIR	0.1	1550.00
GONDELWIESE	0.04	1285.00
	18.00	

The development also utilizes the flow of the following streams:

	Drainage Area (km^2)	Yearly Flow (million m^3)
KAPONIG BACH	13.5	9.9
ZWENBERG BACH	13.8	12.7
MUEHLDORFER BACH	11.75	23.6
GOESS BACH	16.45	19.7
RIECKEN BACH	15.95	19.95
	71.45	85.90

(c) KREUZECK GROUP (Serial No. 29): This group impounds the flows of right bank MOELL River tributaries and conducts the flow to the KOLBNITZ plant for power production. It includes the following elements:

	Drainage Area (km^2)	Yearly Flow (million m^3)
TEUCHL BACH and tributaries	42.24	49.9
GNOPPITZ	31.28	27.5
GRABACH	22.33	21.50
KAISER and NIKLAI BACH	23.75	25.6
	119.61	124.5

Included in the development is the ROSSWIESE "weekly" reservoir of 0.185 million m^3 at elevation 1194.0 m.u.A. Two other "weekly" reservoirs of 0.140 million m^3 are proposed.

g. ISEL River Region.

(1) KAISERBACH Power Plant (Serial No. 22): Isel River Km 20.5. This project has been in operation since 1950. It has 6000 KW capacity and 6.0 m^3/sec mean discharge, a 0.1 million m^3 storage reservoir, and an operational turbine capacity of 3 m^3/sec. (See Reference 30).

(2) Proposed Projects. The following developments are in the planning stage:

(a) POELLAND Power Plant (Serial No. 28) of the City of LIENZ:

30,000 KW capacity

(b) DABERKLAMM-HUBEN Power Development (Serial No. 27) on the KALSERBACH at Isel River Km 20.5. It will have 120,000 KW capacity and include the DORFERTAL Storage Reservoir (Serial No. 27) of 95.0 million m^3 capacity. The DABERKLAMM Dam is to be an arched gravity dam, 140.0 m high with a maximum pool elevation of 1728.00 m.u.A., and a minimum of 1630.0 m.u.A. The utilized head will be 98.00 m. The penstock capacity is to be 17 m^3/sec. (See Reference 31).

(c) MATREI Power Development (Serial Nos. 25, 26 & 27): ISEL River Km 30.0. This project is to be located on the TAUERNBACH (see Reference 30). The planned ultimate capacity is to be 35,000 KW. The project will include the SCHILDALM Power and Pumping Plant of 30,000 KW capacity with the following reservoirs:

	Storage Capacity (million m^3)	Elevation m.u.A.
INNERGESCHLOSS (Serial No. 25)	90.0	1777.00 (max.) 1682.00 (min.)
MATREIR TAUERNTAL (Serial No. 26)	120.0	1593.00 (max.) 1505.00 (min.)
DORFERTAL (DABERKLAMM) (Serial No. 27)	100.00	1730.00 (max.) 1630.00 (min.)

EXHIBIT B

ABSTRACTS OF TECHNICAL LITERATURE

ON THE MUR (MURA) RIVER

RESTRICTED
SECURITY INFORMATION

EXHIBIT B

ABSTRACTS OF TECHNICAL LITERATURE ON THE MUR (MURA)* RIVER

1. INTRODUCTION

a. This exhibit consists of abstracts of information translated from technical literature concerning the physical and hydrologic characteristics of the MUR (MURA) River and the pertinent features of the major hydroelectric power dams in its basin. The information was obtained from American, German, and Austrian technical literature listed as References 14, 22 and 35 to 39, inclusive, in the Bibliography following the text in the main body of this report. In selection of abstracted material, primary emphasis was placed upon hydraulic and hydrologic features that would be of use in the study covered by this report. Reference should be made to the basic sources for other critical features, such as structural and electrical factors. The information available in the sources in many cases is incomplete. However, it is believed that the material presented in this exhibit would assist in determining the relative military hydrologic potentialities of the hydraulic and hydroelectric developments now existing or proposed, within the basin. In addition, this exhibit might be utilized to supplement information obtained from other sources and from field reconnaissance or to serve as a guide to indicate the nature and extent of desirable additional data to be supplied by further research and intelligence procurement.

b. Specific reference is also made to the general map, Plate 1, of the report, for locations of important elements and to Table 4 of the report for summarized pertinent data on hydroelectric structures. Serial numbers of hydroelectric power developments as shown in Table 4 and Plate 1 of the report are included in this exhibit to facilitate identification. The river kilometers cited in this exhibit correspond to the system used throughout the report and described in paragraph 1-04e of the text.

2. GENERAL DESCRIPTION (Basis: References 14, 22, 35)

a. The MUR (MURA) River is the largest tributary of the DRAU (DRAVA) River. It is 455 km long, and has a drainage area of 13,824 km^2, both measured at its mouth at LEGRAD. The MUR is an international river, flowing on the territory of AUSTRIA, YUGOSLAVIA and HUNGARY. The major part of the course lies in AUSTRIA, namely 325.4 km plus 33.4 km length of boundary. The rest of the MUR'S course, including its junction with the DRAU River, is on the territory of YUGOSLAVIA and HUNGARY. Between Km 96 and 130 (new kilometering from the junction with the (DRAU), the MUR River serves as the international boundary between YUGOSLAVIA and AUSTRIA. Also in its lowest reaches between Km 0.0 at LEGRAD and Km 41.0

*MUR is the German and Austrian name; MURA is the Slavic name.

at FELS, the thalweg line of the MUR River serves as the international boundary between HUNGARY and YUGOSLAVIA. Prior to 1918, the MUR was entirely within AUSTRIA-HUNGARY. The administration, however, was divided; the Austrian part being administered from the Central Hydrographic Office in Vienna, and the Hungarian part from BUDAPEST.

b. The MUR River originates in the CENTRAL ALPS at LUNGAU, elevation 1926/* Along its 455 km long course, it drops 1796 m to elevation 130 m.u.A., at LEGRAD in the PANNONIAN DEPRESSION.

c. The geophysical characteristics of the MUR show three distinct divisions:

(1) UPPER MUR, of interior Alpine region, between LUNGAU and BRUECK a.d. MUR, Km 234, following a west to east course.

(2) MIDDLE MUR, crossing the exterior Alps between BRUCK and GRAZ (Km 179) in a north to south direction and through the STYRIAN HILLS in a southeasterly direction to RADKERSBERG, Km 101.4.

(3) LOWER MUR, in the YUGOSLAV-HUNGARIAN DEPRESSION (PANNONIAN DEPRESSION) to the junction with the DRAU River at LEGRAD.

d. The UPPER MUR has all the characteristics of a stream of the CENTRAL ALPS. It flows through a west-east 200 km long escarpment known as "NORISCHE SENKE" (Noric Fault Line Scarp), which also contains the MUERZ River. This part is entirely separated from the neighboring regions and from the Alpine foreland by high mountain ranges such as the LOWER TAUERN, EISENERZ ALPS, RADSTAETTER ALPS on the left, and the HAFFNER GROUP and GURKTALER ALPS on the right. The drainage area of the UPPER MUR is approximately 200 km long and from 30 to 50 km wide. Approximately 2/3 of the flow is supplied by left side tributaries against 1/3 from the right.

e. The MIDDLE MUR. Beginning at BRUCK a.d. MUR (Km 234), the MUR bends sharply southward and cuts across the exterior Alpine mountain range (STEIRISCHE RAND GEBIRGE) to GRAZ (Km 179). There, it enters the so-called "GRAZER BUCHT" or STYRIAN HILLS. The MUR and DRAU Rivers are the only major streams cutting from the interior Alps through this Alpine exterior range towards the east.

f. The LOWER MUR. Below GRAZ, the MUR valley turns southeast and widens until it spreads out towards the east depression at RADKERSBERG (Km 101). It leaves Austrian territory at Km 96.2 and enters YUGOSLAVIA.

3. GEOLOGIC CONDITIONS.

a. The interior Alpine part of the MUR region is predominantly of crystalline character, changing in parts from highly crystalline rock, granite and gneiss formations to metamorphic rocks. Between these, the less metamorphic rocks of various types, such as mica schists and calcareous marble, may be found. The NORTH CALCAREOUS ALPS (NOERDLICHEN KALKALPEN) penetrate only the northeast part of the MUERZ region.

/* m.u.A.

3b

b. Between the CENTRAL ALPS and CALCAREOUS ALPS, northward from the line PALTEN-LIESING-MUR-MUERZ, is a zone of Palezoic graywacke slate, marked by great variation of petrographic composition with a predominance of iron ore. Also important are the Tertiary formations with deposits of coal, particularly along the slump between TAMSWEG BASIN across the SEETALER PASS in the direction of the RANTEN, KATSCH and WOELZER VALLEYS, proceeding further into the basin of JUDENBURG and SEECKAU.

c. The "STEIRISCHE RAND GEBIRGE" (STYRIAN MOUNTAIN RANGE), through which the MUR River cuts its course in a 700-1,300 m deep gorge between BRUCK and GRAZ, is the most easterly part of the CENTRAL ALPS. This range surrounds the depressed "GRAZER BUCHT" (BAY OF GRAZ). Fundamentally, this mountain range is of the same geologic structure as the crystalline system of the UPPER MUR region. The escarpment along the fault line MUR-MUERZ VALLEY-OBDACHER SADDLE-LAVANT VALLEY-MISLING VALLEY separates the STYRIAN mountain range from the CENTRAL ALPS.

d. The "STEIRISCHER HUEGELLAND" (STYRIAN HILLS) known also as "GRAZER BUCHT," through which the MUR flows below GRAZ, is a Tertiary formation, originating in the same geologic period in which the PANNONIAN SEA overran the southern part of STYRIA as far as the Alpine range and then started to recede. A Tertiary sediment of soft schist, sand, clay rubble and gravel formed a several hundred meter thick cover over the original depressed mountains. The whole surface area of the "HUEGELLAND" is characterized by the erosion of numerous streams creating the typical long drawnout chains of low hills and flat wide valleys. The wide diluvial and alluvial gravel fields are also important characteristics of this middle part of the MUR. Such gravel terraces reach a thickness of as much as 80 m.

4. HYDROLOGIC CONDITIONS.

a. General. The MUR is an Alpine stream, defined in official Austrian terminology as a "high mountain river without considerable glaciers in its drainage area." The major part of its region is located at 1,000-2,000 m.u.A., or higher elevations.

b. Seasonal Variation. The maxima and minima of the flow are distributed during the hydrologic year as discussed in following subparagraphs.

(1) Absolute minimum flow of the MUR occurs in the winter months of January and February because of regular freezing conditions in the entire region above 1,000 m.u.A.

(2) Absolute maximum flow occurs regularly in April and May. The snow is usually melted in spring and, in most adverse conditions, in early summer. The glacial reserve which would be apparent in the summer period is lacking.

4b(3)

(3) Beginning in June, a slight decrease of discharge starts which, in the months of July and August, may increase or decrease (secondary minimum), depending upon weather conditions.

(4) At the beginning of autumn, the rains and melting of fresh snow in regions of higher elevations increase the MUR'S flow or delays any decrease of it. (Secondary maximum).

(5) Beginning in November, the flow falls to the usual absolute minimum.

c. Flow Duration. On the basis of official long term information of 1915 (see Reference 22), the flow of the MUR at PEGGAU was:

over	100	m^3/sec	for	a	period	of	185	days
"	80	"	"	"	"	"	220	"
"	70	"	"	"	"	"	260	"
"	60	"	"	"	"	"	270	"
"	50	"	"	"	"	"	300	"
"	40	"	"	"	"	"	330	"

The catastrophic flood at DIONYSEN (km 243.5) was 1,700 m^3/sec.

5. TEIGITSCH POWER DEVELOPMENT (Based on References 27, 36, 37 & 38).

a. General.

(1) The TEIGITSCH project in ARNSTEIN is situated on the TEIGITSCH River and its tributaries, MODRIACHERBACH and PACKERBACH. The TEIGITSCH flows into the KAINBACH River which, in turn, joins the MUR River at WILDON, MUR River Km 155. The development consists of the following installations:

ARNSTEIN Power plant				
LANGMAN Reservoir and Dam				
PACK	"	"	"	(Serial No. 7)
HIERZMAN	"	"	"	(Serial No. 8)

It was constructed in stages, starting with the ARNSTEIN power plant and its "weekly" reservoir, LANGMAN Dam, in 1923-1925. This reservoir retains approximately 0.3 million m^3. PACK Dam was constructed in 1929-1932 as the second step. PACK Dam has its own small power plant. Its main purpose is to serve as a yearly reservoir for the ARNSTEIN power plant. The storage capacity is 5.41 million m^3. HIERZMAN DAM, built in 1948-50 provides additional hydraulic power supply for ARNSTEIN power plant, and has a capacity of 7.8 million m^3. The combined storage capacities of the TEIGITSCH River reservoirs amount to 12.91 million m^3. PACK and HIERZMAN Dams serve to insure an output capacity at ARNSTEIN power plant of 30,000 KW. (See pp 290-291 of Reference 36 and pp 21-25 of Reference 37).

5b

b. ARNSTEIN Power Plant (Basis: Reference 27)(See pp 763, 829, 846, 928 and 1019 of Reference 27). Detailed description of the ARNSTEIN power plant after the recent reconstruction due to the accomplishment of HIERZMAN DAM in 1950 is not available. The power plant capacity is 30,000 KW. (See Figs. 1248, 1344-56, 1582 and 1738 in Reference 27).

c. LANGMAN Dam and Reservoir. (Basis: Reference 27). The dam is a concrete gravity dam of 26 m overall height, 5.0 m crest width, and 26.2 m base width, including the stilling basin and energy dissipator. The total length of the dam is 34.0 m. The spillway has 2 openings each 9.00 wide, equipped with "Freud" shutter gates 1.75 m high. The upper pool elevation is 629.50 m.u.A., when shutters are closed. Two trapezoidal roller-sluice gates close the 5256 m long tunnel of 2.6 m diameter that carries the flow to the penstock and thence to the turbines in the ARNSTEIN power house. (See pp 820-21 of Reference 27). The two penstocks have 1.950 m clear diameter and are connected with the tunnel by a Y-piece enclosed within a concrete block. The penstock serves 3 turbines. (See Figs. 811-813, 821-823, 982, 986, 992, 1030-1034, 1079-1087, 1514-1517, and 1568-69 of Reference 27).

d. PACK Dam and Reservoir (Serial 7) (Basis: Reference 37).

(1) This project was built in 1929-32 for the purpose of increasing and regulating the hydraulic power supply of the ARNSTEIN power plant. Its geographic location is 46° 58'40" north, 15° 01'00" east of Greenwich. The drainage area covers 63 km^2 of wooded territory in the MIDDLE ALPS, lying between 1583 and 839 m.u.A., the mean elevation being 1100.0 m.u.A. Geologically, the area consists mostly of gneiss and mica schists as well as diluvial glacial formations with a weathered cap and thin sediment cover. The stream carries no detritus nor mud.

(2) The dam is located at the confluence of the MODRIACHER-BACH and PACKERBACH. The yearly inflow ranges between 26 and 55 million m^3, and averages 43 million m^3 in a normal year. The retention volume and area of the reservoir are:

Elevation (m.u.A.)	Storage (million m^3)	Area (hectares)
867.70	5.41	58.0 (winter stage)
867.20	5.12	55.8 (summer ")
865.00	4.00	46.7
862.67	3.00	37.7
859.60	2.00	28.7
855.32	1.00	18.5
839.00	0.00	0.0 (lowest stage)

(3) The hydraulic head is 29.0 m above mean water stage. Maximum depth of reservoir at the dam is 29.0 m. The area of the valley cross-section at the dam is 3020.0 m^2. PACK Dam is an arched gravity dam, assymetric with the built-up left wing. Expansion joints are located at intervals of 14.6 to 25.6 m. A central inspection gallery is located inside the dam with shafts on both sides. The measurements of the dam are

as follows:

Crest elevation—86[illegible].2 m.u.A.
Max. height of dam – 33.2 m
Free " " " – 29.2 m

The upstream side of the dam is vertical; the tailwater side is sloped 1:0.75. Free length of the dam is 183 m, extended on the left side by a rock-filled wing dam 79 m long, 13.2 maximum height, 1:2 slope on the upstream side, and 1:2.5 on the downstream side. (See Fig. VII of Plate 9d of this report or Figs. 3, 4a, 9, 10, pp 3, 4, 24 and 25 of Reference 37).

(4) The spillway is designed so as to concentrate the overflow stream into the tailwater in the PACKERBACH. It has 3 sluices 6.7x2.2 m of 130 m^3/sec capacity, equipped with hand-operated gates.

(5) The bottom outlet is a steel pipe 0.90 m diameter tapering to 0.70 m diameter, with a butterfly emergency valve of 0.80 m diameter and a ring valve as regulating main closures. Capacity of the outflow is 7 m^3/sec. A Venturi meter calibrates the flow.

(6) The penstock to the Francis spiral turbine is 1.30 m diameter; it has 2 butterfly valves of 1.20 m diameter. The flow capacity is 3 m^3/sec. The turbine generates 500 KW.

e. <u>HIERZMAN Dam and Reservoir (Serial No. 8) (Basis: Reference 38).</u> This plant serves as an additional "yearly" reservoir for the ARNSTEIN power plant in order to maintain its capacity at 30,000 KW. The outflow is carried by a tunnel of 2.60 m diameter from HIERSMANN Reservoir to the LANGMAN Reservoir. (See Plate 9d of this report for sketches of the dam and Reference 38 for detailed description of the project). The main characteristics of HIERSMANN Dam are:

Location	46°15'N, 15°05'E
Yearly inflow	95.0 million m^3
Retaining reservoir volume	7.2 " "
Area of reservoir	33.0 hectares
Drainage area	160.0 km^2
Maximum stage elevation	708.00 m.u.A.
Minimum " "	675.00 "
Foundation elevation	650.00 "
Crest length	180.00 m
Wall height	58.0 "
Radius of crest (middle)	90.0 "
Radius of lower third	54.8 "
Arch thickness at crest	2.70 "
Lower third thickness	9.9 "
Spillway length	50.0 "
Bypass tunnel length	226.0 "
Bypass tunnel diameter	2.60 "
Bypass closure	2 butterfly valves 1.0 m, and 2 ring valves 0.8 m diameter

6. HYDRAULIC DEVELOPMENTS ON MUR RIVER.

a. General. The MUR River is regulated for purpose of flood protection along most of 350 km long reach lying on Austrian territory and also extensively developed for hydraulic and hydroelectric power generation. However, no substantial regulation of the river exists below the Austrian border on the territory of Yugoslavia. The hydraulic developments in specific reaches is outlined in the following paragraphs.

b. UPPER MUR between km 444.0 - 236.34 at BRUCK a.d.M. In this part of the MUR River, the vertical regulating structures consist of 5 low weirs (sills) for the purpose of reducing the steep stream gradient, and also numerous other fixed and movable weirs utilising the created hydraulic head for power generation in small private industrial enterprises and in a few larger public hydroelectric power plants. Usually the weir across the river diverts the flow into an artificial canal on which are located several small, industrial enterprises. Pertinent features of these developments are as follows:

(1) Km 433.58-433.120, OLLSCHUETZEN Industrial Canal. Fixed wooden overflow weir; 560 m long canal, which accommodates 3 small industrial enterprises; canal mean head 8.45 m; canal and weir under reconstruction because of destruction of weir in war.

(2) Km 432.360-432.100, JEDL Power Plant. Sluice weir with spillway, 2 openings; upper tunnel conduit 94 m long; surge tank; 2 penstocks 0.40 and 0.55 m diameter; power house; 2 Francis turbines, 1.4 m^3/sec flow, 680 KW power capacity.

(3) Km 430.615-429.880, HUHR Industrial Canal. Fixed overflow wooden weir 11.20 m long; 1.45 m wide inlet sluice gate; canal 725 m long, mean head 10.26 m; 1.0 m^3/sec utilized flow capacity; serves 6 small industrial installations.

(4) Km 425.225-425.100, HEMMERACH Industrial Canal. Fixed overflow wooden weir; canal inlet structure with 3 sluices; utilized flow 0.6 m^3/sec; mean head 1.20 m; serves mechanical power unit.

(5) Km 416.600-416.580, ST. MICHAEL-BUERGER Canal. Fixed wooden weir 23.30 m long, in 3 steps each 4.25 m high; canal on right side, serves 2 industrial enterprises and has 3.2 m^3/sec flow capacity, mean head 2.50 m; canal on left side serves 1 enterprise and is 1.5 km long, 1.5 m^3/sec capacity, mean head 10.42 m.

(6) Km 406.770-406.400, UNTERBERG Industrial Canal. Fixed 2 step overflow weir, 14.25 m long, 2.5 m high; canal, with 262 m long head-race and 130 m tail-race, 225 m^3/sec flow capacity, 3.95 m head, serves 4 small industrial enterprises.

(7) Km 395.120-394.520, WADLING MUR Power Plant. Fixed weir with overflow, idling chute and sandtrap, spillway length 15.70 m; 232 m long head-race; 2 Francis turbines, 9 m^3/sec flow and 500 HP capacity; mean head 5.50 m.

(8) Km 362.520-362.400, MURAU Power Plant. Fixed weir, 15 m long, log-way 10 m wide; scouring sluice 6.60 m wide; head-race 30 m long, 4.85 m wide; 3 turbines, [illegible].2 m^3/sec flow, 400 KW power capacity; mean head 5.2 m.

(9) Km 344.660-344.[illegible]0, FRAUENHOF Power Plant. Fixed weir; head-race with 5 sluice gates, 58 m long; 10.27 m wide, 1.70 m deep; 2 turbines, 12.5 m^3/sec.

(10) Km 313.400-313.350, JUDENBURG Power Plant. Fixed overflow weir; power house directly on MUR River Bay; 3 Francis turbines, 32 m^3/sec, 770 KW; mean head 4.1 m.

(11) Km 312.650-312.50, JUDENBURG Power Plant of STEIRISCHER GUSSTAHLWERKE A. G. 2 separated fixed overflow weirs; 4 Francis turbines, 51 m^3/sec flow, 1,100 KW power capacity; mean head, 2x3.6 m.

(12) Km 253.170-252.300, LEOBEN Power Plant. Automatic roof weir with log-way; 700 m long head-race; 3 turbines, 50 m^3/sec flow, 1670 KW power capacity.

(13) Km 249.00-245.65, NIKLASDORF Power Plant. 1 movable weir and 1 fixed-roof weir; 10 Francis turbines, 72 m^3/sec flow; 3,050 KW power capacity; 5.0 m and 6.0 m mean hydraulic head.

(14) Km 243.50-239.90, DIONYSEN Power Plant (Serial No. 9): movable weir with 3 openings; sluice gates 15 m x 6.3 m. Weir capacity 1,700 m^3/sec corresponding to the catastrophic flood water; backwater length 1.5 km; approximate reservoir storage capacity 1.5 million m^3; power plant canal 3.73 km long, flow capacity 75 m^3/sec, bottom gradient 0.02 percent, cross-section of trapezoidal shape, bottom width 4.5 m, slopes 1.0 to 1.5; inlet structure on left side equipped with curtain wall; 3 inlet double sluices each 6.7x4.8 and 5 scouring sluices 4.0x1.2 m; 2 Kaplan turbines each 47 m^3/sec and 7,500 HP capacity; mean utilized hydraulic head 16.75 m; movable crane, 45 tons load capacity.

(15) Km 238.20-236.00, BRUCK-OBERDORF Power Plant. Roof weir with log-way; upper canal 1.5 km long; 5 Francis turbines, 45 m^3/sec, 3,000 KW capacity. (See pp 687-8, Reference 27).

c. MIDDLE MUR - Between BRUCK (km 236.24) and RADKERSBURG (km 98.31).

(1) Km [illegible]-226.[illegible] [illegible] (Serial No. 10): movable sluice weir with 3 openings and 2 concrete pillars; double sluice gate 15 m clear width and 11.80 m high (upper leaf 8.30 m; lower leaf 3.3 m);

emergency closure by means of stop-logs; upper stage 467.3 m.u.A.; backwater length 4.3 to 5.4 km; canal inlet structure on right side, equipped with a curtain wall 6.07 m long, 1.50 m submerged depth; canal closure by means of 3 double sluices, each 5.3 m x 5.00 m; 1 waste sluice; upper canal 2.32 km long, flow capacity 140 m^3/sec, trapezoidal cross section, bottom width 9.5 m, slopes 1:1.5 bottom gradient 0.025 percent; 3 Francis vertical shaft spiral turbines each 45 m^3/sec and 8,300 HP capacity; capacity of power plant 18,500 KW; mean utilized head 17.3 m. (See pp 598-762 of Reference 27 or Fig. VI of Plate 9c of this report).

(2) Km 222,725-214,840. LAUFNITZDORF Power Plant (Serial No. 11). Submersible cylindrical weir, 2 openings, 25 m wide and 6.3 m high; both cylindrical gates may be sunk 1.25 m under the normal stage; weir drive mechanism on the middle pillar; emergency closure by means of needles; upper stage 448.3 m.u.A.; backwater length approximately 4 km; canal inlet structure on right side equipped with curtain wall and coarse trash rack, 7 waste sluices each 4.20 m x 0.90 m and 3 double sluices 6.40 m x 3.80 m; 65 m long spillway over the canal wall into the river; upper water canal 6.95 km long, 110 m^3/sec flow capacity, trapezoidal cross-section, bottom width 6 m, side-slopes 1:1.5, bottom gradient 0.025 percent, concrete facing; surge tank constructed separately from the power house; 2 penstocks equipped with gates 8.6 m x 2.62 m with hydraulic drive, emergency closure by means of stop logs; 4 waste sluices each 1.25 m^2; 2 Kaplan turbines with vertical shafts, 55 m^3/sec and 11,000 HP capacity; power plant capacity 16,000 KW; mean utilized head 19.0 m; movable crane 75 ton load capacity.

(3) Km 213,665-213.00, FROHNLEITEN Power Plant and Paper Mill. Sector weir with 4 openings; 3 openings, 16.00 m x 3.85 m, equipped with sluice gates 2.77 m high and a 1.08 m high flap; 1 log-way 11.0 m wide and 22.5 m long; upper pool stage 428.00 m.u.A.; canal inlet structure equipped with 7 sluices 4.00 m wide plus a sandtrap; 3 Francis turbines with vertical shafts, 80 m^3/sec flow and 2,500 KW power capacity; mean hydraulic head 4.0 m.

(4) Km 212.09-211.00, FROHNLEITEN MAYR-MELNHOF Paper Mill. Fixed weir 55.3 m long; 6 turbines, 43 m^3/sec flow, and 865 KW power capacity; mean hydraulic head 3 m.

(5) Km 205.185-200.79, PEGGAU Power Plant (Serial No. 12). Built in 1911 together with the LEBRING development, Serial No. 14, (described below); concrete sluice weir with 5 openings and 4 pillars consisting of 2 fixed overflow weirs, each 13.8 m long with movable flap 1.50 m high, 2 under sluices 12 m wide, and 1 log-way 11 m wide; canal inlet structure with 4 sluices, each 5.20 m wide; upper canal 3.14 km long, partly open and partly in tunnel; 5 Francis twin turbines with horizontal shafts, 80 m^3/sec flow capacity; power capacity 7,200 KW; mean head 11.60 m. (See pp 686-790, Reference 27).

(6) Km 200.69-199.75, PEGGAU-HUNNAGEL Mill and Power Plant. Upper stage 397.40 m.u.A.; 680 m long cofferdam separating the inlet canal from the MUR River Bay; capacity of canal 36 m^3/sec; 3 vertical turbines 370 HP capacity; hydraulic head ...

(7) Km 191.26-189.35. GRATWEIN Power Plant (Serial No. 13). Hydraulic roof weir consisting of 2 openings each 22 m wide, 1 log-way 10 m wide and 25.8 m long, and 2 under sluices 10 m wide; all openings with power-operated gates; old canal to mill, 22 m^3/sec flow capacity with 4 double sluices each 3 m wide; new canal to power plant, 76 m^3/sec flow capacity equipped with 5 double sluices each 3.40 m wide; 5 Francis turbines and 2 Kaplan turbines; total power capacity 4,830 KW.

(8) Km 184.275-157.945. GRAZ Right-side Canal: 28.5 km long; old development now serving 28 different mills, power plants, etc.; upper WEINZOETTEL weir, 62.5 m long, a fixed structure, providing the necessary hydraulic head; log-way 24.8 m long permitting operation of floating rafts; canal inlet equipped with 2 sluice openings 7.10 m wide and 1.62 m high.

(9) Km 183.970-179.114. GRAZ Left-side Canal: 5.36 km long, serving 9 mills, factories and hydroelectric power plants; fixed overflow weir, total length 240 m; log-way with sluice gate; open canal inlet on the left side of river equipped with a 188.5 m spillway leading into MUR River; inlet structure of 3 openings 3.0 m x 2.30 m and 2 waste sluices 3.22 m x 2.57 m.

(10) Km 167.14-162.565. FERNITZ-MELLACHER Industrial Canal: 5.75 km long serving 3 industrial installations.

(11) Km 163.7-141.70. MELLACH-WEISSENEGGER Canal: 22.3 km long, serving 13 installations including 3 power plants; inlet structure of canal, 4 openings equipped with sluice gates; flow capacity 14.5 m^3/sec.

(12) Km 152.435-151.245. LEBRING Power Plant (Serial No. 14): constructed simultaneously with PEGGAU Power Plant (Serial No. 12) and of the same type; sluice weir, 5 openings and 4 midstream pillars, total length 77 m, 2 openings 14 m x 3.5 m, 2 under sluices 14 m x 4.15 m and 1 log-way 13 m x 142 m, 34 m long; all openings equipped with sluice gates, power-operated; upper stage 287.7 m.a.s.; upper pool width 157.0 m; canal inlet structure 65 m wide, consisting of inlet lock 25 m long with 9 openings 2.60 m wide and 3.17 m high, and an under sluice 4.0 m wide; upper canal 1,040 km long, maximum bottom width 21 m; 92 m long spillway into MUR River at end of the canal; 4 Francis twin turbines 20 m^3/sec flow and 15.85 HP capacity; maximum power capacity 4,100 KW and 99.0 m^3/sec; hydraulic head 6.60 m.

(13) Km 135.21-129.76. EHRENHAUSEN Canal: 5.7 km long, serving 5 installations including hydroelectric power plants.

(14) Km 134.90-121.40. STRASS CANAL: 14.6 km long, serving 5 industrial installations, mostly very old.

(15) Km 119.615-98.310. RADKERSBURG-MURECK Left-side Canal: 25.5 km long, serving 14 industrial power developments and various small mills.